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Research Article

Foraminifera Abundance in the Southern Waters of Sumbawa, Senunu Canyon, West Sumbawa, Sumbawa, West Nusa Tenggara

Resti Samyati Jatiningrum[1]*, Gina Mulhimatul Aliyah[1], Anggun Mutika[1], Yunia Witasari[2]
1)Geological Engineering Study Program, Faculty of Exploration and Production Technology, Universitas Pertamina, Jl. Teuku Nyak Arief, Jakarta 12220, Indonesia
2)Research Center for Limnology and Water resources, National Research and Innovation Agency of Indonesia (BRIN), Jl. Raya Jakarta-Bogor Km. 45, Bogor 16917, Indonesia
* Corresponding author, email: resti.sj@universitaspertamina.ac.id

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ABSTRACT
The Southern Waters of Sumbawa, Senunu Canyon, West Nusa Tenggara, is influenced by the Indonesian Throughflow (ITF), crucial for regional marine dynamics. This area also faces impacts from mining tailings discharged into the seabed, raising concerns about their impacts on meiobenthic fauna, including foraminifera. This study examined changes in foraminiferal assemblages, abundance, and diversity using 20 gravity core samples from sites NM.021 and NM.023. The results revealed a diverse and abundant presence of foraminifera, with planktonic foraminifera dominating in terms of abundance compared to benthic foraminifera, as indicated by an average P/B ratio exceeding 90 %. Twelve species of planktonic foraminifera and 17 species of benthic foraminifera were identified, with distinct compositions across the sites. At site NM.021, the most abundant benthic foraminifera were *Bulimina* sp. (23.5 %), *Ceratobulimina pacifica* (18.7 %), and *Hoeglundina elegans* (13.3 %), while dominant planktonic foraminiferal taxa consisted of *Hastigerina pelagica* (21.6 %), *Pulleniatina obliquiloculata* (17.8 %), and *Neogloboquadrina dutertrei* (17.4 %). At site NM.023, the most abundant benthic foraminifera were *Bolivinita quadrilatera* (22.3 %) and *Ceratobulimina pacifica* (21.8 %), while the planktonic foraminiferal taxa showed similar dominance, with *Pulleniatina obliquiloculata* (20.8 %), *Hastigerina pelagica* (15 %), and *Neogloboquadrina dutertrei* (13.3 %) being the most abundant. The study highlights warm, eutrophic conditions with potential upwelling, indicated by planktonic species *Pulleniatina obliquiloculata* and *Neogloboquadrina dutertrei*. Additionally, these waters also have low oxygen levels (dysoxic), as evidenced by the presence of benthic species *Bulimina* sp. and *Ceratobulimina pacifica.*

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INTRODUCTION

Southern Waters of Sumbawa is one of the waterways traversed by the Indonesian Throughflow (ITF) pathway, making it compelling to study and important to understand due to its significant impact on both Indonesian and global climate conditions. One of the bioindicators that can be used to assess the condition of the waters is foraminifera. Foraminifera are single-celled microorganisms commonly found in brackish to deep-sea environments. While some foraminifera have adapted to a planktonic lifestyle, the majority are benthic. Their distribution is primarily affected by abiotic factors including temperature, salinity, oxygen levels, light, substrate type, turbidity, and nutrient availability. Various species assemblages are typical of different water depths, environments, and latitudinal zones (Pawlowski 2009). This makes foraminifera a potential indicator for understanding both ancient and modern marine environmental conditions.

Administratively, Southern Waters of Sumbawa are located in Sumbawa Regency, West Nusa Tenggara Province. The morphology of these waters consists of basins and ridges influenced by several factors including geological processes, submarine rock formations, sedimentation processes, and geodynamic activities, including the potential impact of mining activities in the area. Mining activities in this area produce tailings waste, while the tailings have been classified as non-hazardous to marine biota (Gwyther et al. 2009), the distribution of which affects the morphology around the tailings pipe outlet (Noviadi et al. 2011). Specifically, the seafloor morphology in this area consists of ridges with steep slopes, causing sediment movement that makes it unstable. This sediment instability can impact the ecosystem, affecting the ecology and the presence of organisms such as meiofauna (Susetiono et al. 2020). In general, the Southern Waters of Sumbawa have depths ranging from 0 to 4600 meters below the surface. Shallow depths are near coastal areas while the deepest parts are southwest of Sumbawa Island (LIPI 2018). Sea surface temperatures in Southern Waters of Sumbawa are relatively warm, ranging between 26-28 °C at a depth of 5 meters. The sampling locations for the research area can be seen in Figure 1.

Marine investigations in the Southern Waters of Sumbawa were conducted by the Oceanography Team of the Oceanographic Research Center Laboratory of the Indonesian Institute of Sciences (LIPI) in 2018. Additionally, there have been numerous studies conducted in the Southern Waters of Sumbawa, including research analyzing the relationship between meiofauna abundance and the presence of tailings in sediments by Susetiono et al. (2020). Other studies by Putra and Nugroho (2019), Zhang et al. (2019), and Ardi et al. (2021, 2023) provide additional insights into the marine environment of the region. There is still a lack of research specifically focusing on the abundance and distribution of foraminifera, particularly in areas influenced by the presence of tailings. This study aims to address this gap, contributing to a more comprehensive understanding of local marine ecosystems of the Southern Waters of Sumbawa.

MATERIALS AND METHODS

Materials

The data used in this research are the abundance and distribution data of foraminifera microfauna from 20 samples, collected from 2 gravity cores, each 50 cm in length. The samples were extracted at 5 cm intervals, with 10 samples taken from each core, from two sites, NM.021 at a depth of 2173 meters and NM.023 at a depth of 2018 meters, in the Southern Waters of Sumbawa. The selection of these sites was based on their proximity to the tailing pipeline, with NM.021 located along the path of the pipeline and NM.023 positioned outside its influence. This approach was intended to facilitate comparative analysis to assess the impact of tailings on the abundance and distribution of benthic foraminifera and to investigate differences in environmental conditions between the impacted and non-impacted sites.

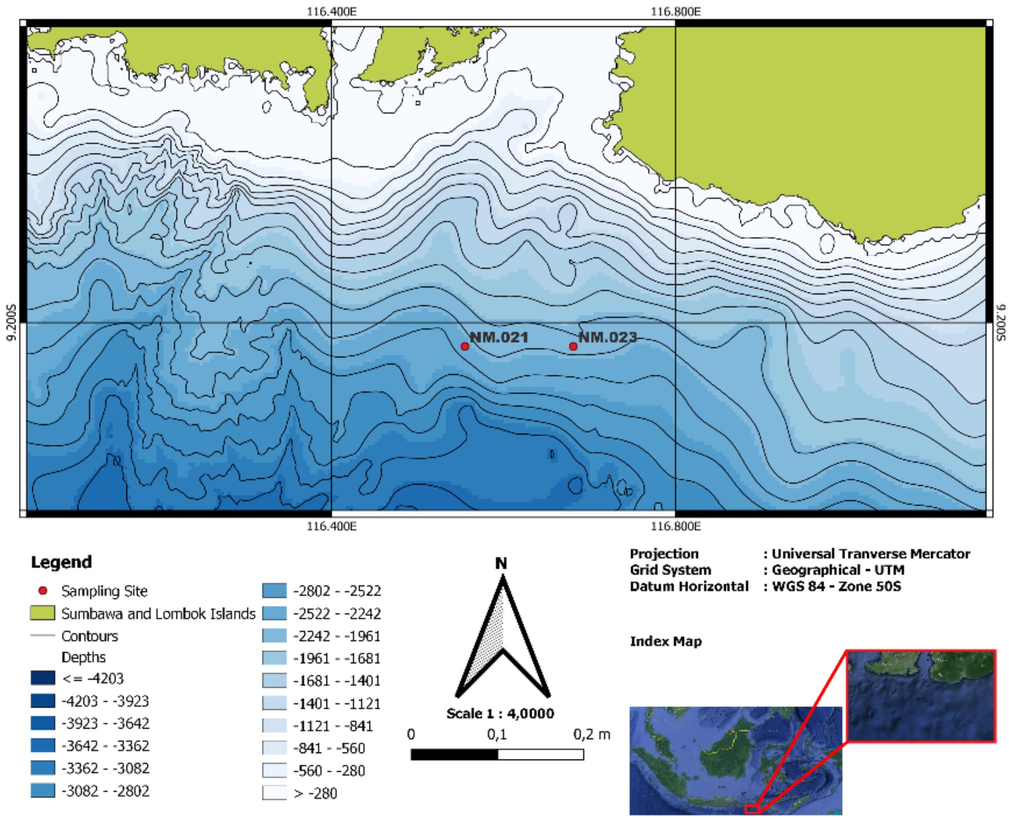

Figure 1. Location of research and sediment sampling in the Southern Waters of Sumbawa.

Methods

Sediment samples were prepared and analyzed at the Oceanographic Research Center Laboratory of the National Research and Innovation Agency of Indonesia (BRIN) located in Ancol, North Jakarta. The equipment used in the research included oven, sieve mesh, scale, splitter, binocular microscope, digital camera, and PAST software (Paleontology Statistical 3) to calculate diversity index. Samples were cut into 5 cm segments, dried at 80 °C for 24 hours, and weighed. They were then soaked in hot water for 2 hours to disaggregate the sediment and sieved using a granulometry mesh for grain size separation. The fractions were dried again, weighed, and stored in plastic bags by size. For foraminifera analysis, 1 gram of the 60 mesh (0.25 mm) size fraction was taken from the net weight obtained in the granulometric analysis. Subsequently, approximately 300 foraminifera shells were separated from the sediment material within each sample. In cases where the sample volume was large and contained abundant foraminifera shells, the sample was divided into several parts using a splitter. The identification of foraminifera was conducted using references from Postuma (1971), Bolli et al. (1985), Loeblich and Tappan (1994), and Holbourn et al. (2013). Determination was also referred to foraminiferal websites including http://www.foraminifera.eu, http://www.marinespecies.org (World Register of Marine Species, WoRMS), and https://www.mikrotax.org.

Quantitative Analysis

Relative Abundance

Relative abundance of foraminifera is determined through quantitative analysis involving the calculation of the percentage of each species relative to the total number of individuals in each sediment sample, which will be presented in Table 1 and Table 2, using the formula (Murray 2006):

$$Relative\ abundance = \frac{Ni}{N}\ x\ 100\%$$

With:
Ni = total number of individuals of species
N = total number of foraminifera in one sample

P/B ratio

The P/B ratio represents the percentage of planktonic foraminifera in the total foraminiferal community (Phleger 1951). The P/B ratio provides information about the depth of marine waters. Under normal marine conditions, the P/B ratio tends to be higher in deep-sea environments compared to shallow marine waters. The calculation of the P/B ratio is done using the formula:

$$\frac{P}{B} Ratio = \frac{P}{(P+B)}\ x\ 100\%$$

With:
P = number of planktonic individuals
B = number of benthic individuals

Diversity index calculation (H')

The Shannon-Wiener diversity index (H') is calculated to determine ecological conditions. The index ranges and their ecological implications are as follows (Bakus 1990):

- H' < 1.0: Low – The environment indicates high ecological pressure, low productivity, and a disturbed ecosystem.
- 1.0 < H' < 3.0: Moderate – The environment indicates moderate ecological pressure, moderate productivity, and a slightly disturbed ecosystem.
- H' > 3.0: High – The environment indicates low ecological pressure, high productivity, and a stable ecosystem.

The Shannon-Wiener diversity index equation is calculated as follows (Bakus 1990):

$$H' = -\sum_{i=1}^{n} \mathrm{Pi}\ .\ln Pi$$

With:
H' = Shannon-Wiener index
Pi = Proportion of species i
N = Individual n

Evenness index (E')

The evenness index analysis uses the Buzas and Gibson (1969) equation:

$$E' = \frac{e^H}{S}$$

With:
E' = Evenness index
H' = Diversity index
S = Number 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

Dominance index (D)

The dominance index value is calculated using the following formula (Gibson

& Buzas 1973):

$$D = (\frac{ni}{N})^2$$

With:
D = Dominance index
ni = Total number of individuals of species i
N = Total number of individuals in the total 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

RESULTS AND DISCUSSION

Based on the identification results, the foraminifera found at the two sites in the study area consist of 12 species of planktonic foraminifera (Figure 2a) and 17 species of benthic foraminifera (Figure 2b), with different foraminiferal contents at each site (Table 1 and Table 2). The abundance of foraminifera at both sites shows that the number of planktonic foraminifera is more dominant compared to benthic foraminifera. At site NM.021, the average P/B ratio percentage is 98.95 % based on 10 depth samples (Figure 3a), whereas at site NM.023, the average P/B ratio percentage is 98.77 % from 10 depth samples (Figure 3b). The high percentage of planktonic foraminifera may indicate that the study area is part of a bathyal environment. Planktonic foraminifera live in the water column, and the water depth of all sediment samples is more than 200 m.

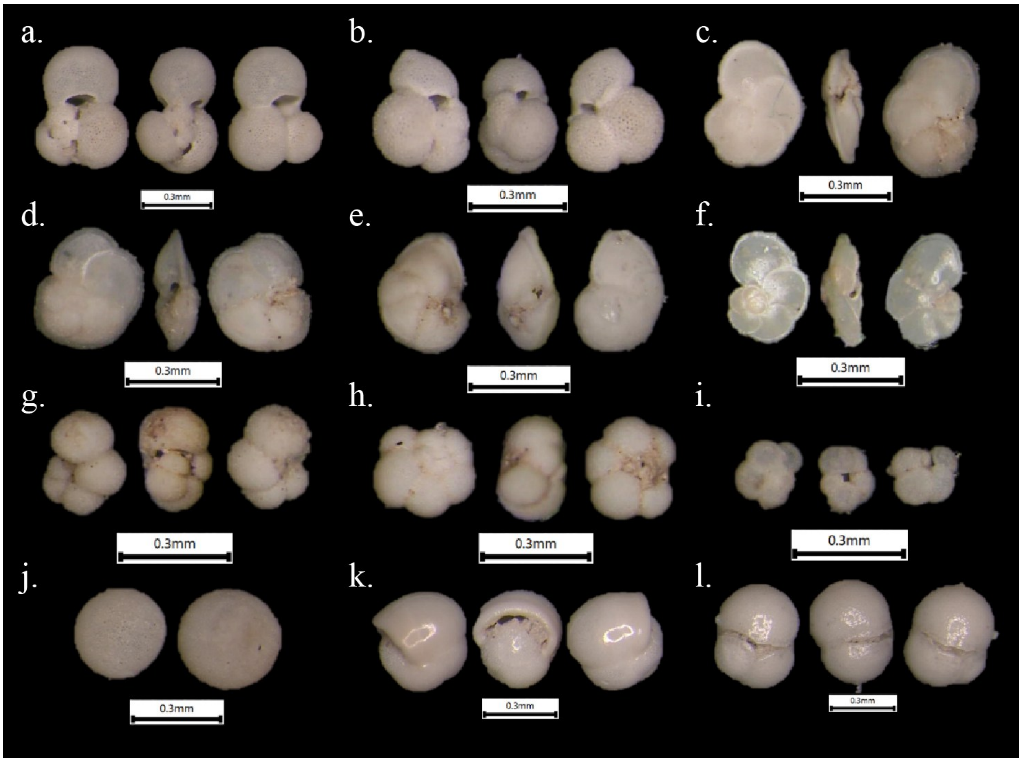

Figure 2a. Dorsal, peripheral, and ventral appearances of planktonic foraminifera. a. *Globigerinoides sacculifer*, b. *Globigerinoides sacculifer* (1), c. *Globorotalia cultrate*, d. *Globorotalia menardii*, e. *Globorotalia tumida*, f. *Globorotalia ungulata*, g. *Hastigerina*, h. *Neogloboquadrina dutertrei*, i. *Neogloboquadrina dutertrei* (1), j. *Orbulina universa*, k. *Pulleniatina obliquiloculata*, l. *Sphaeroidinella dehiscens*.

The diversity index values at both research sites have an average of 2.25 (Figure 4). The low dominance value, averaging 0.13, contrasts with the high evenness value, averaging 0.67. This indicates that the research area still supports the growth of foraminifera (Buzas & Gibson 1969; Gibson & Buzas 1973). This indication is further supported by the abundant and diverse presence of foraminifera at both sites (Bakus 1990).

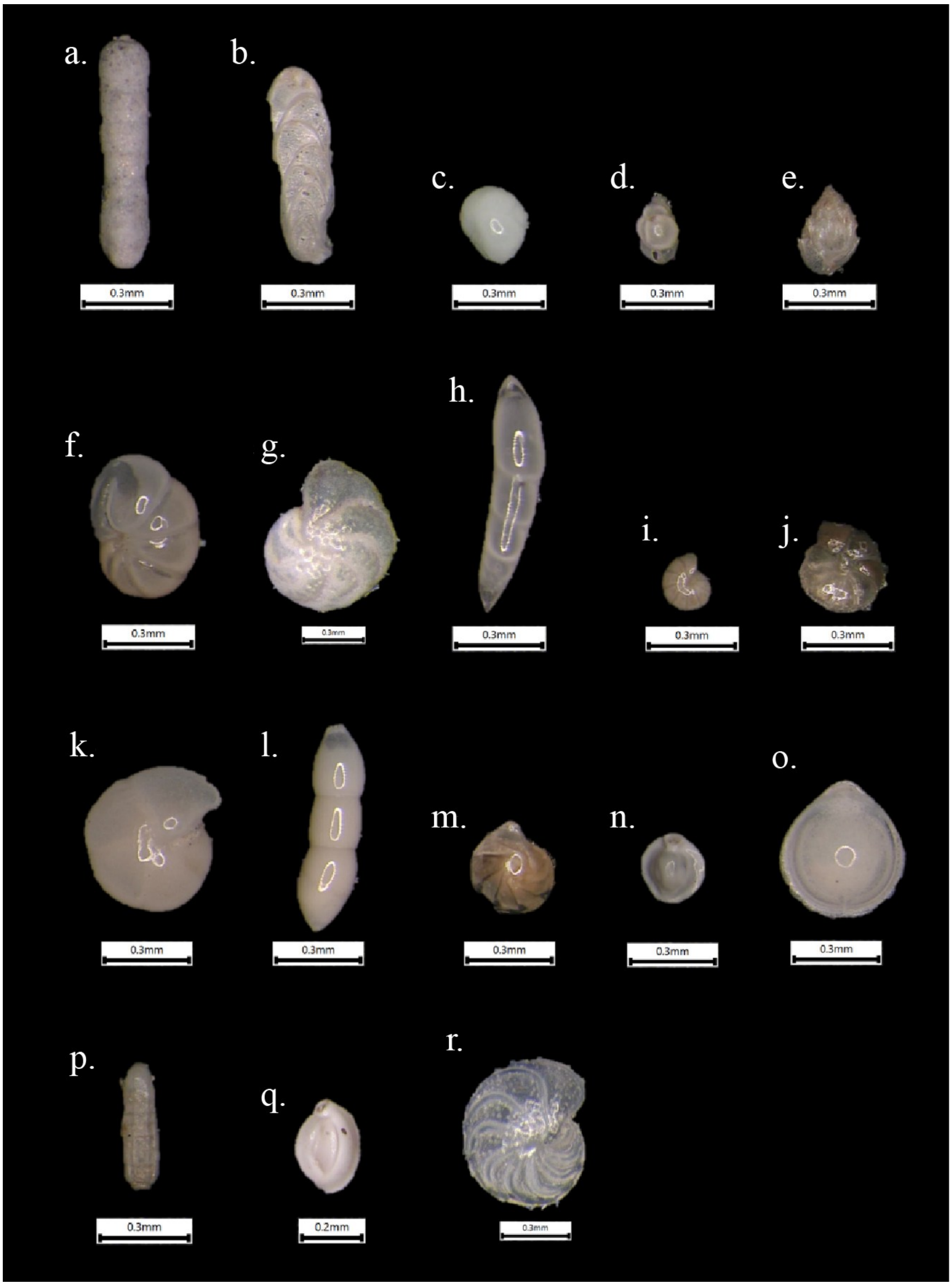

Figure 2b. Benthic foraminifera. a. *Ammobaculites* sp., b. *Bolivinita quadrilatera*, c. *Bolivina* sp., d. *Bulimina marginata*, e. *Bulimina* sp., f. *Ceratobulimina pacifica*, g. *Cibicides*, h. *Dentalina decepta*, i. *Gyroidina orbicularis*, j. *Heterolepa bradyi*, k. *Hoeglundina elegans*, l. *Laevidentalina*, m. *Lenticulina submamiligera*, n. *Pyrgo alata*, o. *Pyrgo lucernula*, p. *Siphogenerina raphanus*, q. *Triloculina* sp., r. *Rosalina bertheloti*.

Planktonic Foraminifera

Planktonic foraminifera have a very high abundance in the study area. These planktonic foraminifera live in the water column, thus their presence is abundant in open deep-sea areas, while in shallow seas their abundance is relatively less. At site NM.021, 12 species of planktonic foraminifera were found with a total number of 30,316 individuals. The most abundant planktonic foraminifera found at this site were *Hastigerina pelagica* (21.6 %), *Pulleniatina obliquiloculata* (17.8 %), and *Neogloboquadrina dutertrei* (17.4 %) (Figure

Table 1. Distribution and number of foraminifera speciments (%) in marine sediment at Site NM.021.

Site	Sample depth	Benthic Foraminifera													Planktonic Foraminifera											
		Ammobaculites sp.	*Bolivina* sp.	*Bolivinita quadrilatera*	*Bulimina marginata*	*Bulimina* sp.	*Ceratobulimina pacifica*	*Cibicides*	*Gyroidina orbicularis*	*Heterolepa bradyi*	*Hoeglundina elegans*	*Pyrgo alata*	*Pyrgo lucernula*	*Triloculina* sp.	*Globigerinoides sacculifer*	*Globigerinoides sacculifer* (1)	*Globorotalia cultrata*	*Globorotalia menardii*	*Globorotalia tumida*	*Globorotalia ungulata*	*Hastigerina pelagica*	*Neogloboquadrina dutertrei*	*Neogloboquadrina dutertrei* (1)	*Orbulina universa*	*Pulleniatina obliquiloculata*	*Sphaeroidinella dehiscens*
NM.021	0-5 cm	0	0	0	0	37,5	25	0	12,5	0	25	0	0	0	8,3	3,7	5,5	8,6	0	1,1	15,5	17	15,1	0	24,7	2
	5-10 cm	0	33,3	0	0	0	0	0	0	33,3	33,3	0	0	0	21,48	7,03	1,11	1,48	0	7,77	35,55	8,51	0	1,11	15,92	4,81
	10-15 cm	42,9	0	0	0	14,3	28,5	0	0	0	0	14,3	0	0	13,78	1,75	11,14	5,57	2,34	1,17	24,63	21,4	0	0	15,18	3,51
	15-20 cm	0	12,5	0	12,5	12,5	0	25	0	0	25	0	12,5	0	11,05	2,3	10,36	3,45	3,22	1,61	18,89	17,51	8,29	0	23,27	1,38
	20-25 cm	0	0	0	33,3	33,3	33,3	0	0	0	0	0	0	0	18,29	1,24	4,78	1,87	1,03	0,83	27,02	20,16	6,86	0,41	17,46	1,45
	25-30 cm	0	0	0	0	50	50	0	0	0	0	0	0	0	13	4,25	4,25	5	1	0,75	16	24,5	12,5	0,75	18	0,75
	30-35 cm	0	0	50	0	50	0	0	0	0	0	0	0	0	14,44	2,66	9,55	2,66	2,22	1,55	14,88	22,88	16	0	13,11	0,88
	35-40 cm	0	0	0	0	0	0	0	0	0	50	0	50	0	11,02	2,85	8,57	3,26	1,42	1,02	27,75	11,02	11,42	0,61	18,97	2,04
	40-45 cm	0	0	0	0	0	50	0	50	0	0	0	0	0	17,86	1,3	11,98	4,57	1,96	3,26	16,33	15,03	9,58	0,21	15,9	1,96
	45-50 cm	0	0	0	0	37,5	0	12,5	0	0	0	25	0	25	18,03	1,59	9,36	2,28	0,68	1,36	19,17	15,52	14,38	0,45	15,06	2,05

Table 2. Distribution and number of foraminifera speciments (%) in marine sediment at Site NM.023.

Site	Sample depth	Benthic Foraminifera															Planktonic Foraminifera											
		Ammobaculites sp.	*Bolivina* sp.	*Bolivinita quadrilatera*	*Bulimina* sp.	*Ceratobulimina pacifica*	*Dentalina decepta*	*Gyroidina orbicularis*	*Heterolepa bradyi*	*Hoeglundina elegans*	*Laevidentalina*	*Lenticulina submamiligera*	*Pyrgo alata*	*Pyrgo lucernula*	*Rosalina bertheloti*	*Triloculina* sp.	*Globigerinoides sacculifer*	*Globigerinoides sacculifer* (1)	*Globorotalia cultrata*	*Globorotalia menardii*	*Globorotalia tumida*	*Globorotalia ungulata*	*Hastigerina pelagica*	*Neogloboquadrina dutertrei*	*Neogloboquadrina dutertrei* (1)	*Orbulina universa*	*Pulleniatina obliquiloculata*	*Sphaeroidinella dehiscens*
NM.023	0-5 cm	0	0	44,44	0	11,11	0	0	0	11,11	0	0	0	0	22,22	11,11	10,18	3,19	7,61	9,09	9,33	3,68	10,31	11,54	11,05	0,49	20,88	1,96
	5-10 cm	0	0	50	0	0	0	0	0	0	0	0	0	50	0	0	12,98	5,19	6,49	0	0	0	20,77	12,98	14,93	0	24,02	2,59
	10-15 cm	0	0	0	0	25	25	0	0	25	0	0	0	25	0	0	9,36	2,41	9,66	2,41	6,64	5,43	13,59	17,82	6,34	0,9	21,75	3,62
	15-20 cm	0	0	25	25	25	0	0	0	0	0	0	0	0	0	25	9,04	0	6,11	2,92	2,12	3,45	20,21	16,22	22,6	0	16,48	0,79
	20-25 cm	0	0	0	0	20	0	0	0	20	0	0	0	0	0	60	9,85	2,95	0	9,35	3,44	3,44	15,27	12,31	17,24	0,24	23,15	2,7
	25-30 cm	0	0	0	0	50	0	0	50	0	0	0	0	0	0	0	12,73	3,5	3,82	10,19	0	3,5	15,6	7,96	18,47	0,95	21,97	1,27
	30-35 cm	16,67	0	33,33	0	16,67	0	0	16,67	0	16,67	0	0	0	0	0	11,29	5,76	5,29	5,06	5,76	2,99	22,58	11,05	9,9	0,46	16,82	2,99
	35-40 cm	0	0	50	0	0	0	0	0	0	0	0	50	0	0	0	15,47	3,13	6,43	2,43	2,26	1,91	12,86	15,47	18,43	1,04	18,08	2,43
	40-45 cm	0	50	0	25	0	0	25	0	0	0	0	0	0	0	0	11,03	2,64	3,97	7,28	2,42	0,66	10,59	11,92	10,81	1,1	24,06	13,46
	45-50 cm	0	0	20	0	70	0	0	0	0	0	10	0	0	0	0	9,27	6,13	10,25	7,1	3,15	2,16	7,88	16,17	10,45	1,18	20,51	5,52

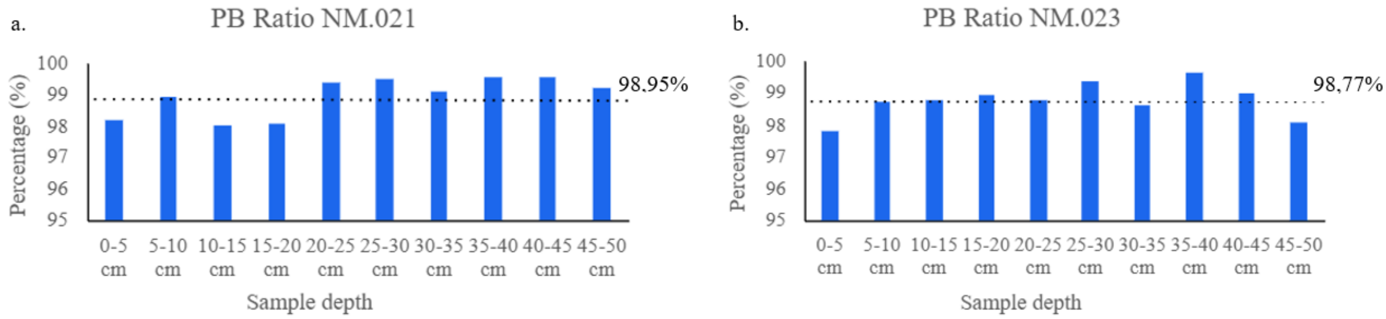

Figure 3. P/B Ratio percentage at Site NM.021 (a) and Site NM.023 (b).

5). Meanwhile, at site NM.023, the planktonic foraminifera found consists of 11 species, with a total of 26,370 individuals. The most abundant planktonic foraminifera at this site are *Pulleniatina obliquiloculata* (20.8 %), *Hastigerina pelagica* (15 %), and *Neogloboquadrina dutertrei* (13.3 %) (Figure 6). In general, the abundant foraminifera found at site NM.023 are similar to those at site NM.021.

The high abundance of *Pulleniatina obliquiloculata* and *Neogloboquadrina dutertrei* indicates that the study area in the Southern Waters of Sumbawa has a high nutrient content, as these species are abundant in the thermocline layer and tend to thrive in warm, productive waters (Troelstra et al. 1989; Ding et

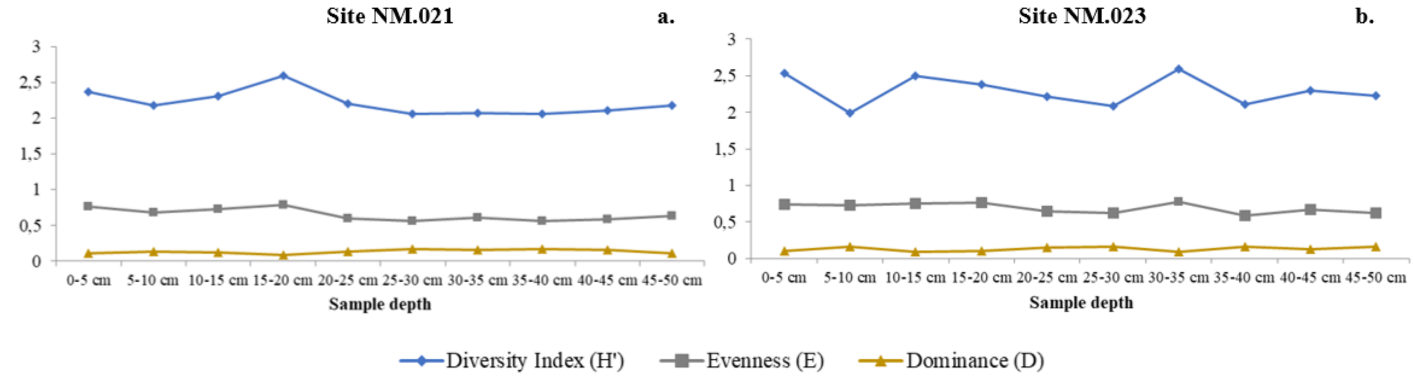

Figure 4. Foraminiferal indices chart in Southern Waters of Sumbawa at site NM.021 (a) and NM.023 (b).

al. 2006). *Pulleniatina obliquiloculata* is a species that lives and is widely distributed in tropical seas and is associated with the presence of abundant phytoplankton (Ravelo et al. 1990; Baohua et al. 1997; Pflaumann & Jian 1999). The consistent presence of *Neogloboquadrina dutertrei* at all sample depths also characterizes eutrophic environments with low salinity (Barmawidjaja et al. 1993; Ding et al. 2006). *Hastigerina pelagica*, a tropical-subtropical species, prefers warm waters with high salinity (Bé & Hutson 1977; Hull et al. 2011). Another planktonic foraminifera species found in abundance and present at all sample depths is *Globigerinoides sacculifer*, a tropical species tolerant of a wide range of temperatures but preferring relatively warm and oligotrophic waters (Pflaumann & Jian 1999; Ding et al. 2006).

Benthic Foraminifera

Benthic foraminifera have a much lower abundance compared to planktonic foraminifera in the study area, but they exhibit higher diversity than planktonic foraminifera. Seventeen species have been identified, with some frequently occurring individuals such as *Bolivinita quadrilatera*, *Ceratobulimina pacifica*, *Bulimina* sp., and *Hoglundina elegans*. At site NM.021, benthic foraminifera found consisted of 13 species with a total of 336 individuals. The most abundant benthic foraminifera at this site were *Bulimina* sp. (23.5 %), *Ceratobulimina pacifica* (18.7 %), and *Hoeglundina elegans* (13.3 %) (Figure 5). Meanwhile, at site NM.023, benthic foraminifera found consisted of 15 genera with a total of 344 individuals. The most abundant benthic foraminifera at site NM.023 were *Bolivinita quadrilatera* (22.3 %) and *Ceratobulimina pacifica* (21.8 %) (Figure 6).

The species *Bulimina* sp. and *Ceratobulimina pacifica*, which were found to be abundant at site NM.021, are indicative of environments with minimum oxygen content (dysoxic) and rich in organic carbon (Rathburn et al. 1996; Martins et al. 2015; Psheneva et al. 2017). Meanwhile, at site NM.023, the abundance of *Bulimina* sp. decreased, and *Bolivinita quadrilatera* was found to be the most abundant species. *Bolivinita quadrilatera* is a benthic foraminifera species that thrives in moderately oxygenated (suboxic) conditions (Kaiho 1991, in Aksu et al. 2002), suggesting a possible increase in oxygen levels at site NM.023.

The planktonic foraminifera, dominated by *Pulleniatina obliquiloculata*, *Neogloboquadrina dutertrei*, and *Hastigerina pelagica*, indicate that the waters of Sumbawa are warm, nutrient-rich conditions, productive waters, characterized by eutrophic environment and possible upwelling events (Troelstra et al. 1989; Barmawidjaja et al. 1993; Ding et al. 2006). Similarly, the study by Gustiantini et al. (2018) in the Arafura Sea also found *Pulleniatina obliquiloculata* and *Neogloboquadrina dutertrei*. The benthic foraminifera indicates that the environmental conditions in the Sumbawa waters generally have low oxygen levels (dysoxic), as evidenced by the abundance of *Bulimina* sp. and *Ceratobulimina pacifica* (Rathburn et al. 1996; Martins et al. 2015; Psheneva et al. 2017). However, there are some changes in oxygen levels indicated by the presence of *Hoeglundina elegans*, which is a marker of oxic conditions and a species sensitive to low oxygen levels (Caulle et al. 2015). At sites NM.021 and NM.023, despite indications of oxygen fluctuations shown by benthic foraminifera, the high diversity index values indicate that the tailings do not affect the foraminifera. As mentioned in the study by Susetiono et al. (2020), the disposal of tailings in the waters of Sumbawa has been managed very well, with the tailing's disposal pipeline located below the thermocline layer. Therefore, the changes in the abundance of benthic foraminifera are more likely caused by sediment instability rather than the presence of tailings.

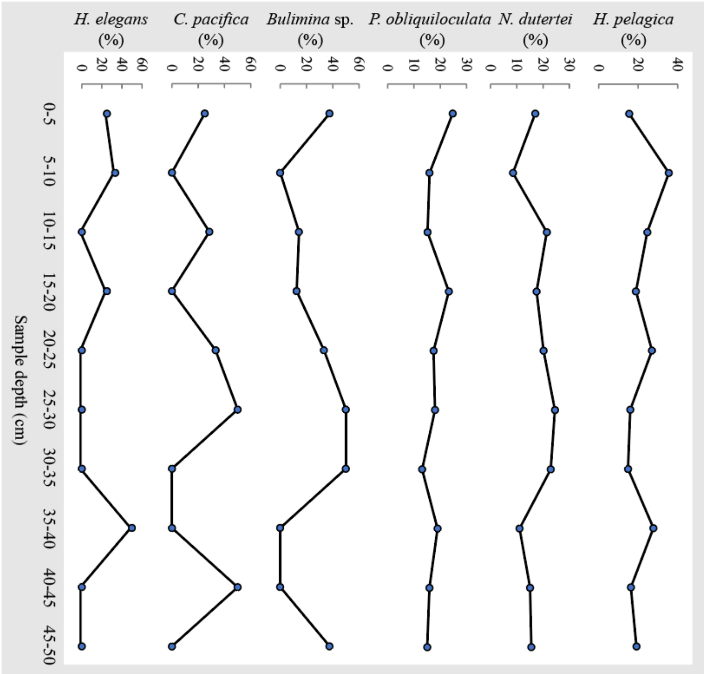

Figure 5. Dominant foraminiferal assemblages identified at site NM.021.

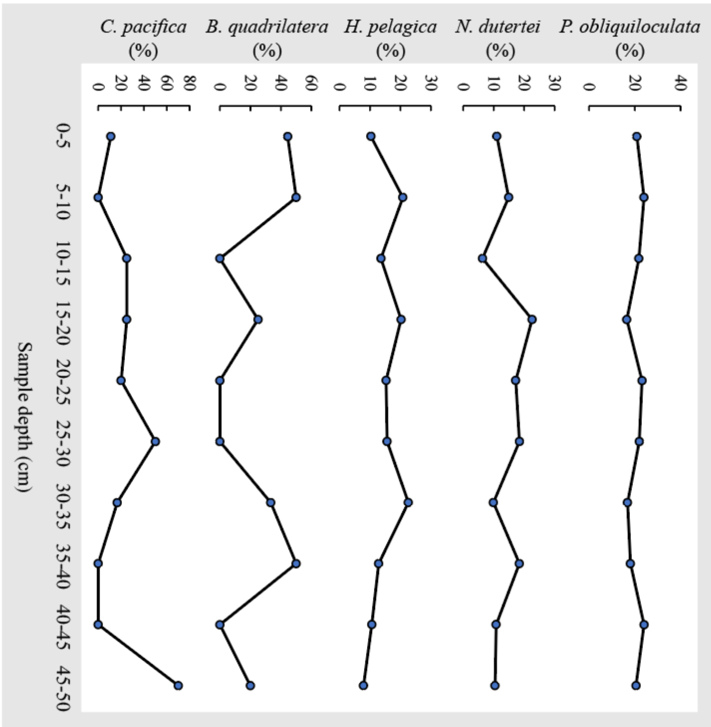

Figure 6. Dominant foraminiferal assemblages identified at site NM.023.

CONCLUSION

The observation of foraminiferal assemblages at sites NM.021 and NM.023 in the Sumbawa Waters revealed the presence of 12 planktonic foraminifera species and 17 benthic foraminifera species. The majority of the planktonic species identified include *Hastigerina pelagica*, *Pulleniatina obliquiloculata*, *Neogloboquadrina dutertrei*, and *Globigerinoides sacculifer*. Meanwhile, the dominant benthic species are *Bolivinita quadrilatera*, *Ceratobulimina pacifica*, *Bulimina* sp., and *Hoglundina elegans*.

The abundance of foraminifera at both sites indicates that the Sumbawa Waters are considered relatively stable for foraminiferal growth, as reflected by the high diversity index values. In general, the conditions in the Sumbawa Waters are characterized by warm and eutrophic waters, with the potential for upwelling events, as indicated by the presence of *Pulleniatina obliquiloculata* and *Neogloboquadrina dutertrei*. The presence of benthic species such as *Bulimina* sp. and *Ceratobulimina pacifica* suggests low oxygen (dysoxic) environment, although the presence of *Hoeglundina elegans*—an indicator of oxygen-rich conditions—suggests occasional increases in oxygen levels. Despite these variations, the consistently high diversity index at both NM.021 and NM.023 suggests that tailing disposal activities do not significantly impact the foraminiferal communities. This observation aligns with Susetiono et al. (2020), who reported that tailing disposal in Sumbawa waters has not adversely affected the marine ecosystem.

AUTHORS CONTRIBUTION

R.S.J. designed, supervised the research process, and wrote the manuscript; G.A.M. and A.M. collected and analyzed the data; and Y.W. supervised the entire project.

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CONFLICT OF INTEREST

There are no conflicts of interest related to the research activities and funding .

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