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COMMUNITY STRUCTURE OF BENTHIC FORAMINIFERA IN EASTERN WATERS OF SEGARA ANAKAN LAGOON IN CILACAP

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ABSTRACT

Benthic foraminifera are types of organisms that are sensitive to environmental changes, so they are often used as a bioindicator for aquatic environmental conditions. The purpose of this study was to determine the community structure of benthic foraminifera community, sediment types and the relationship between the abundance of foraminifera with the sediment types in the eastern waters of Segara Anakan Lagoon in Cilacap. Method used in this study was a survey method. Samples were taken by using random sampling method. The study was conducted at 5 stations with 3 repetitions. Laboratory observations carried out included the types and numbers of benthic foraminifera. Community structure of foraminifera among stations were analyzed using one-way ANOVA, while the relationship between community structures and water quality parameters was analyzed using Pearson correlation. The results showed that in the the eastern waters of Segara Anakan Lagoon there were 58 species of foraminifera which abundance ranged from 532 ind/m^2 to 927 ind/m^2. The diversity index of foraminifera was in the medium to high diversity categories. The uniformity index of foraminifera was in the high uniformity in a stable community. The dominance index of foraminifera was in the low category. The sediment types was fine sand, medium sand and coarse sand. The relationship between the abundance of foraminifera with the sediment types was strong with high R values (0.763-0.809).

Keywords: benthic, community structure, Foraminifera, sediment, Segara Anakan Lagoon

INTRODUCTION

The Segara Anakan Lagoon is located between the southern part of the Java Island and the Nusa Kambangan Island (180°53' - 109°30' W; 7°20' - 7°35' S), with an area of about 240 km^2, extending from west to east. This area is a protected water area with a closed tropical forest (Setyowati 2005). Industrial activities and residential areas that continue to increase, as well as the rapidly growing tourism areas causes adverse impacts on the surrounding ecosystem (Setyowati 2005). One way to see the impact is to investigate the habitat of an organism in a community (Ferawati *et al.* 2014). Biological component analysis in an ecosystem is a measurement of biological responses to changes in environmental conditions, which can be studied through a community of organisms that are used as parameters of important biological components (Fachrul 2007).

One of the important organisms in marine ecosystems, especially in shallow seas, is benthic foraminifera. Foraminifera organisms are shelled organisms that are abundant in various marine environments. In a volume of 1 cm^3 of sediment, there can be hundreds of living foraminifera individuals, along with many dead shells (Sadough *et al.* 2013; Bawole *et al.* 2017). Foraminifera is among the organisms in seabed sediments that can indicate the environment conditions of their living area. Their way of life is by attaching themselves to sediments, rocks, marine plants and corals available at the bottom of the waters. As a result, benthic foraminifera are very sensitive to various environmental changes such as temperature, salinity, light and

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pH (Gustiantini 2008). Therefore, foraminifera are widely used by biologists, geologists and oceanographers in relation to various changes in marine environmental conditions (Boltovkoy & Wright 1976 in Sidiq *et al*. 2016).

Foraminifera are single cell organisms having hard shells and most of their communities live in the sea. The numbers of foraminifera found in the waters worldwide, both planktonic and benthic, are around 12,000 species (Puspasari *et al*. 2012). The wide distribution area of foraminifera in various types of aquatic environment has the potential to assist in understanding environmental conditions in a waters (Rositasari 2006). The living condition of foraminifera are strongly influenced by micro- and macro-environmental conditions, which makes foraminifera potential to be used as an indicator for environmental changes (Rositasari 2011).

Information on the types and community structure of foraminifera in the waters of the Segara Anakan Lagoon is still very limited and not much studies have been done. On the other hand, knowledge about the community structure of foraminifera can be used to determine the ecological conditions of a waters (Sen Gupta 2003; Sadough *et al*. 2013), because the distribution of foraminifera is strongly influenced by the surrounding environmental conditions, so that certain species can reflect certain ecological conditions (Gustiantini 2008).

This study aimed to determine: 1) the types and community structure of benthic foraminifera, sediment types and 2) the relationship between the foraminifera abundance and sediment types in the waters of the Segara Anakan Lagoon.

MATERIALS AND METHODS

The study was conducted in the eastern waters of the Segara Anakan Lagoon in Cilacap by using a survey method. Data collection was done by random sampling method. Foraminifera samples were observed in the laboratory of the Faculty of Fisheries and Marine Sciences of Universitas Jenderal Soedirman. The laboratory observations identified the types and numbers of foraminifera collected from the sediment samples.

The observational station consisted of 5 stations. Samples were taken from each station with three repetitions. The measured water quality parameters were salinity, temperature, pH and brightness. Sediment samples were taken using a sediment grab. The samples were stored in the sample sticks, transported to and analyzed in the laboratory. The collected sediment samples were washed, then ovendried. After the samples' temperature reaching room temperature, the samples were sieved using a multilevel sieve.

The sifted dry samples were weighed and sprinkled onto a surface, followed by identification of the foraminifera (Armstrong & Brasier 2005; Barker 1960; Loeblich & Tappan 1994; Yassini & Jones 1994; Sadough *et al*. 2013; Gupta 2003).

Research parameters observed were the types and community structure of benthic foraminifera, such as abundance, diversity, uniformity and dominance. The abundance of foraminifera is the number of individuals of a species occupying a certain area. Diversity index (H') is used to measure the degree of ecological instability in a system. The uniformity index is an index used to measure the even distribution of species abundance in a community. Dominance index is used to determine the extent to which a group of biota dominates another group (Bawole *et al*. 2014; Insafitri, 2010; Odum 1994).

The data from the study were analyzed descriptively. Differences in foraminifera community structure among stations were analyzed using one way ANOVA, while the relationship between foraminifera abundance and sediment types was analyzed using Pearson correlation. Data processing was done by using SPSS software version 17.0.

RESULTS AND DISCUSSION

Foraminifera Community Structure

The number of benthic foraminifera species found in the eastern waters of Segara Anakan Lagoon was 58 species. At station 1 there were 22 foraminifera species with the most abundant

species at this station was *Elphidium craticulatum*. There were 13 foraminifera species at station 2, while at station 3 there were 25 species of foraminifera. The most common species found at stations 2 and 3 was *Ammonia beccarii*. At station 4 there were 26 species with the most species was *Operculina ammonoides*. There were 31 species of foraminifera found at station 5 with the highest number of species being *Amphistegina hauerina* (Fig. 1).

The highest number of foraminifera species was found at Station 5 (31 species), while the lowest foraminifera species was found at Station 2 (13 species). *Ammonia beccarii, Ammonia falsobeccarii* and *Elphidium craticulatum* were foraminifera species found in all research stations. These species has high adaptability and high tolerance to various environmental conditions compared to other species. According to Uthicke (2008), foraminifera of the genus *Elphidium* are indicators of high turbidity levels and low brightness. This finding is in agreement with the work of Toruan (2011) which stated that foraminifera from the genus *Elphidium* and *Ammonia* are included in the opportunist group which are tolerant to adverse environmental conditions compared to other foraminifera.

The species *Amphistegina hauerina* and *Operculina ammonoides* were foraminifera species that were only found at stations 4 and 5. It is suspected that stations 4 and 5 are coral reef areas with the characteristics of clear waters with high brightness. Foraminifera of the genus *Amphistegina* are the most abundant foraminifera of the coral reef symbiotic group in waters with a fairly high level of brightness (Toruan 2011). In general, foraminifera from the genus *Amphistegina* are the most well-known species associated with coral reef areas (Eichler *et al.* 2019). Foraminifera of the genus *Amphistegina* are important ecosystem builders because of their contribution to calcium carbonate production and thrive in a variety of shallow water habitats. The genus *Amphistegina* is also a bioindicator to determine the quality of clean water in the coastal environment (Weinmann *et al.* 2013).

The abundance, diversity, uniformity and dominance indices were used to determine the foraminifera community structure in the eastern waters of Segara Anakan Lagoon.

Foraminifera Abundance

The abundance of foraminifera found in the eastern waters of Segara Anakan Lagoon ranged from 532 to 927 ind/m^2 (Fig. 2).

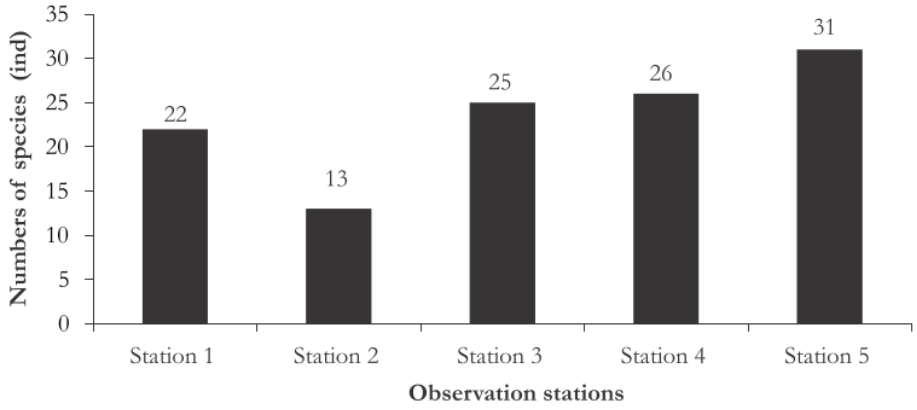

Figure 1 Average numbers of benthic foraminifera in the eastern waters of Segara Anakan Lagoon

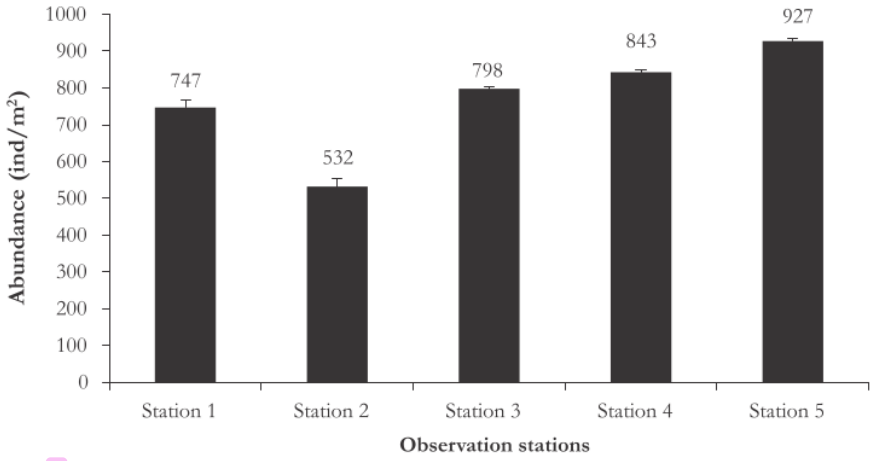

Figure 2 Abundance of benthic foraminifera in the eastern waters of Segara Anakan Lagoon

The highest number of benthic foraminifera was found at station 5 with 927 ind/m^2, while the lowest number was found at station 2 with 532 ind/m2. Station 5 had the highest abundance of benthic foraminifera, presumably because this station is an open area that is directly affected by the water currents (higher water currents). Station 2 had the lowest abundance of foraminifera, because this station tends to be more protected from water currents (lower water currents). High velocity of water currents can affect the distribution of benthic foraminifera in a waters. Gustiantini (2008) stated that the distribution of benthic foraminifera is influenced by current patterns; in relatively speedy water currents conditions the foraminifera species will be very abundant and diverse. The presence of water current will evenly distribute the water temperature and salinity. In addition, water currents also play a role in carrying food for foraminifera (Toruan 2011; Uthicke 2008).

Diversity Index (H')

The biota diversity can be determined using the Shannon-Wiener index (H'). In this study, the diversity index of foraminifera in the eastern waters of Segara Anakan Lagoon ranged from 2.29 to 3.11 or falls into the medium to high diversity categories. The diversity index at station 1 was 2.43. Station 2 had diversity index of 2.29. Station 3 had diversity value of 2.94, while the index for station 4 was 3.03 and the index for station 5 was 3.11 (Fig. 3). The diversity index in this study showed that the stations have suitable water quality conditions as the habitat for foraminifera in terms of nutrients suppy availability, lighting, temperature, salinity and pH. This finding is supported by Gustiantini (2008) which stated that the life of foraminifera organisms is strongly influenced by abiotic factors such as temperature, salinity, brightness, pH and sediment types.

Water quality measurements obtained in the eastern waters of Segara Anakan Lagoon showed that the water temperature at all stations ranged from 26 °C to 29 °C. This temperature range is suitable for the habitat of foraminifera organisms, which can be found at temperature range of 10 - 30 °C (Pranajaya 2015). According to Rositasari (1997) temperature affects the metabolism of an organism and foraminifera can live and adapt to a certain temperature range. The critical point of temperature can be reached when the foraminifera reproduction process is no longer taking place (Rositasari 1997).

In this study, the water salinity ranged from 29 to 31 ppt. The salinity range corresponds to the habitat of benthic foraminifera which can be found in salinity range of 18 - 30 ppt (Rositasari 1997). Waters with normal salinity usually has a high diversity of foraminifera species (Rositasari 1997). Foraminifera organisms are also able to adapt to low salinity, such as bays, brackish waters and swamps, which are usually inhabited by foraminifera with agglutinin shell type. Foraminifera are also able to live in waters having high salinity. The high salinity waters

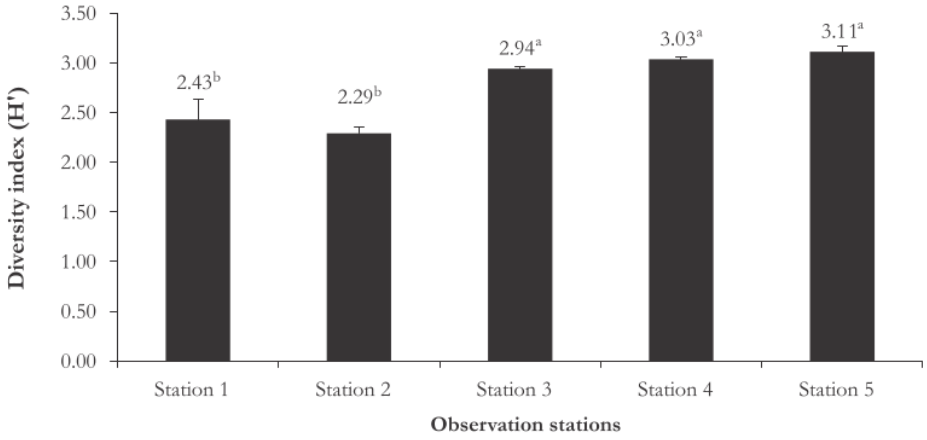

Figure 3 Diversity of benthic foraminifera in the eastern waters of Segara Anakan Lagoon

(hypersaline waters) are favored by foraminifera species with porcelain shell types having high concentrations of calcium carbonate (Rositasari 1997).

The water brightness in this study was in the range of 1.1 - 2.1 m which is below the brightness quality standard of sea water of > 3 meters based on the Kepmeneg LH (2004). The low brightness in the eastern waters of Segara Anakan Lagoon is due to the fact that the area is close to the river mouth, which is a meeting place between river waters and sea waters. River waters carry wastes from the land and the process of mixing seawater and freshwater causes the waters to become muddy due to the mixing of particles from the mainland (Saraswati *et al.* 2017).

The pH values ranged from 6 to 7. Water pH affects the growth of foraminifera organisms, because the degree of acidity of a waters can affect the biological activity of foraminifera organisms, one of which is the shell formation process (Yanti 2016). Waters with acidic water conditions can cause a reduced ability of foraminifera to secrete calcium carbonate in shell formation (Brasier 1980).

The analysis of variance (ANOVA) results showed that there was a significant difference in diversity index of benthic foraminifera ($P < 0.05$) among stations. Stations 1 and 2 had significant differences in diversity index to stations 3, 4 and 5. The differences are presumably due to the different characteristics of the study locations. Stations 3, 4 and 5 have characteristics of open environment, while stations 1 and 2 have characteristics of a more protected environment. The open area is affected by the current velocity which tends to be greater than the one in the protected area. Current velocity can affect the distribution of foraminifera in a waters. The distribution of foraminifera in the waters is influenced by currents, sediment types and the presence of coral reefs (Gustiantini 2008).

Uniformity Index (E)

The uniformity index is an index used to measure the even distribution of species abundance in a community. This index provides information about the similarity of species living among stations. The uniformity index of foraminifera in the eastern waters of Segara Anakan Lagoon enters the category of high uniformity, stable community, ranging from 0.82 to 0.94. The uniformity index at station 1 was 0.82 (the lowest). The uniformity index at station 2 was 0.92.

Station 3 had a uniformity index of 0.93. The uniformity index at station 4 was 0.94 (the highest). The uniformity index at station 5 was 0.93 (Fig. 4).

The uniformity index (E) from all stations was > 0.6 which means that the uniformity at each research station enters the high category with stable community. If the distribution of organisms in an ecosystem is evenly distributed, the ecosystem tends to be in a stable condition (Odum 1994). The evenness of species presence

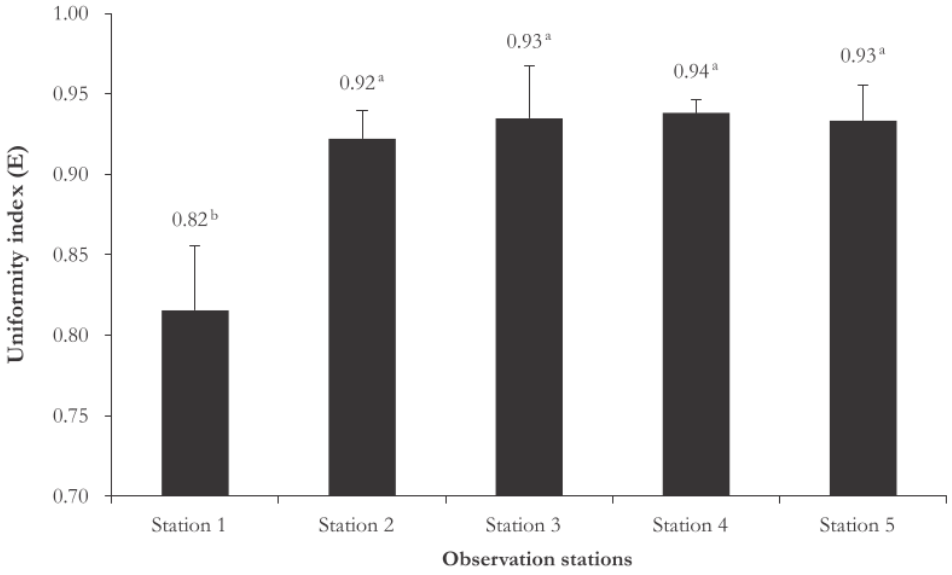

Figure 4 Uniformity index of benthic foraminifera in the eastern waters of Segara Anakan Lagoon

at each research station is supported by the morphology of foraminifera having the ability to exist in various ecosystems. Benthic foraminifera as single-cell shelled organisms have the ability to occupy various marine areas ranging from the supertidal zone above the littoral to the deepest depths in the hadal abbysal zone (Bawole *et al.* 2017).

Our study showed that there was a significant difference ($P < 0.05$) in the uniformity index of benthic foraminifera among stations, i.e., the uniformity index at station 1 was significantly different from that at stations 2, 3, 4 and 5.

Dominance Index (C)

The dominance index shows the dominant value of species abundance at each station. The greater the value, the dominant the species at the station. Our study showed the dominance index ranging from 0.0535 to 0.1182 which enters the low category (Fig. 5).

The highest dominance index was found at station 1 ($C = 0.1182$), while the lowest index was found at station 5 ($C = 0.0535$). The dominance index values of all stations are in the range of 0.00 - 0.50, which enters the low category. The dominance index in a community structure is usually inversely proportional to diversity index. The low dominance value (< 0.5) indicates that the foraminifera organisms are highly diverse and more evenly distributed. The low dominance index shows that no species dominates (Bawole *et al.* 2017).

Sediment Types

The sediment types in the eastern waters of Segara Anakan Lagoon are fine sand to coarse sand. Stations 1 and 2 had fine sand sediment type. Station 3 had a medium sandy sedimen type, while stations 4 and 5 had coarse sand sediment type (Fig. 6).

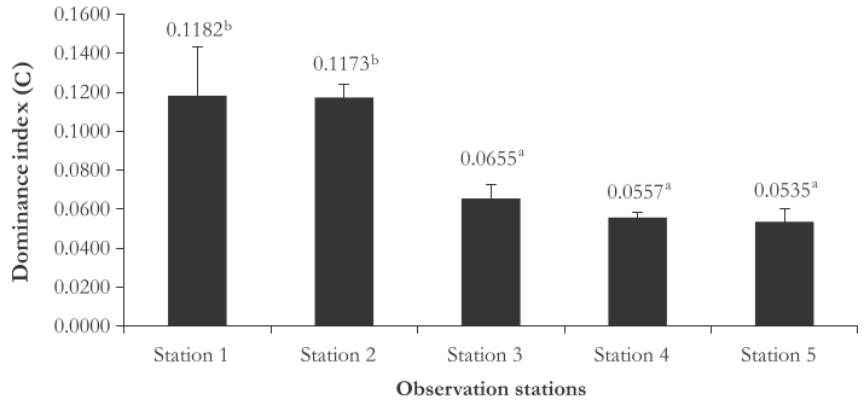

Figure 5 Dominance index of benthic foraminifera in the eastern waters of Segara Anakan Lagoon

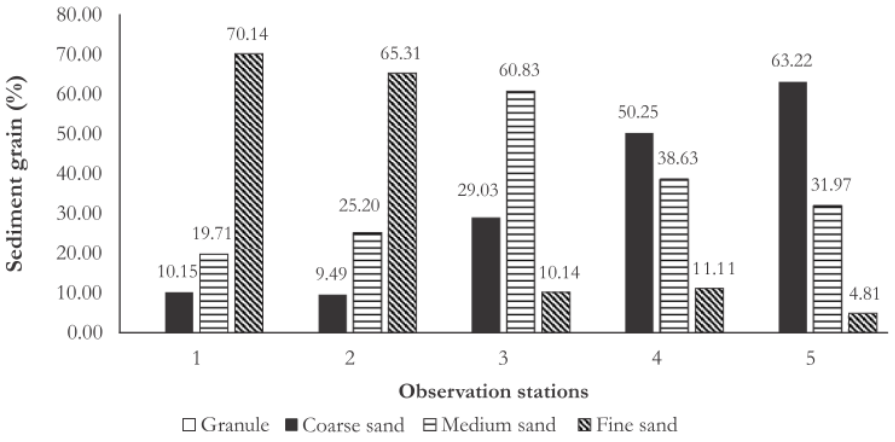

Figure 6 Percentage of sediment types in the eastern waters of Segara Anakan Lagoon

The fine sand sediment was found at stations 1 and 2, presumably because these two stations are close to the river mouth, which is more protected than other stations. A relatively protected area has a lower water movement resulting to smaller size particles (Aritonang *et al.* 2014). Stations 4 and 5 have coarse sand sediment, presumably because these two stations are close to the beach, which are open areas and have relatively higher water currents. A strong water currents will cause the sediment to have coarser fractions, so that the sediment is not easily carried away by the water current (Bayhaqi 2015).

Relationship between Benthic Foraminifera Abundance and Sediment Types

The Pearson correlation analysis showed relationship between the foraminifera abundance with sediment types. The correlation values ranged from a low but definite relationship (R = 0.331) to a high and strong relationship (R = 0.763 - 0.809) (Table 1).

The foraminifera abundance was strongly related to the coarse sand sediment type (0.809) and fine sand sediment type (-0.763). On the contrary, a low but definite relationship occurred between the foraminifera abundance to the medium sand type (0.331). The negative

Tabel 1 Relationship between foraminifera abundance and sediment types

		Coarse sand	Medium sand	Fine sand
Abundance	Pearson correlation	0.809**	0.331	-0.763**
	Sig. (2-tailed)	0.000	0.228	0.001
	N	15	15	15

Note: ** = Correlation is significant at P < 0.01.

value in the correlation between foraminifera abundance and fine sand sediment type indicated inversely proportional relationship, which meant that the finer the sediment type, the less the foraminifera abundance is. These findings are supported by the work of Natsir (2010) which states that foraminifera organisms generally occupy sediments containing sand; no foraminifera are found in mud and silt sediment types. The work of Lacuna (2013) also supported our findings which stated that the sediment types affect the presence of foraminifera, because foraminifera generally are more abundantly found in the sandy sediment type and less abundant in a finer sediment type.

CONCLUSION

The sediment types and water current affect the foraminifera abundance and distribution. Water quality parameters among observation stations are relatively similar and have no significant effect on the abundance and distribution of foraminifera.

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