# DISTRIBUTION OF BENTHIC FORAMINIFERA IN THE WATERS FROM OFF PUTRI ISLAND, NORTHERN BATAM, RIAU ARCHIPELAGO

# *DISTRIBUSI FORAMINIFERA BENTIK DI PERAIRAN SEKITAR PULAU PUTRI, UTARA BATAM, KEPULAUAN RIAU*

**Resti Samyati Jatiningrum[1*], Anggun Mutika[1], Luli Gustiantini[2], Nineu Yayu Gerhaneu[2], Godwin Latuputty[2], and Agustina Rosi Divina[1]**

[1] Geological Engineering Program Study, Faculty of Exploration and Production Technology, Universitas Pertamina, Jl. Teuku Nyak Arief, Jakarta 12220, Indonesia

[2] Marine Geological Institute of Indonesia, Jl. Junjunan No. 236 Bandung, 40174 Indonesia, Geological Agency, Ministry of Energy and Mineral Resources

*Corresponding author: resti.sj@universitaspertamina.ac.id

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**ABSTRACT**: Putri Island is the outermost island bordering Singapore, located north of Batam City, Riau Archipelago Province. A total of 29 sediment samples were collected from the seafloor off Putri Island for foraminiferal study. The purpose of this study is to determine their abundance and distribution related to previous data of environmental conditions. For this study, we analysed quantitative analysis of benthic foraminifera including its abundance, diversity, dominance, and evenness indices. The results denoted that benthic foraminifera was composed of 62 species that belonged to 31 genera. The diversity index was categorized as a moderate to high diversity index (1.85-3.12), with a low to high evenness index (0.37 – 0.78), and a low dominance index (0.05-0.24). This indicates that in general the waters of Putri Island are considered to have a fairly good environment and are quite stable for foraminiferal growth. A slight environmental stability degradation occurred in the north eastern part of the study area which demonstrates high levels of pollutants in the waters. This situation influent the benthic assemblages which are indicated by lowering index diversity at that location.

**Keywords**: Benthic foraminifera, Quantitative analysis, Putri Island, North Batam Waters.

***ABSTRAK***: *Pulau Putri merupakan salah satu pulau terluar yang berbatasan dengan Singapura yang terletak di utara Kota Batam, Provinsi Kepulauan Riau. Sejumlah 29 sampel sedimen diambil dari dasar laut Pulau Putri untuk studi foraminifera. Tujuan dari penelitian ini adalah untuk mengetahui kelimpahan dan distribusi foraminifera serta kaitannya dengan data kondisi lingkungan sebelumnya. Untuk studi ini, kami melakukan analisis kuantitatif foraminifera bentik antara lain kelimpahannya, indeks diversitas, indeks dominansi, serta indeks keseragamannya. Hasil penelitian menunjukkan bahwa foraminifera bentik di Perairan Pulau Putri mengandung sekitar 62 spesies foraminifera bentik, yang termasuk ke dalam 31 genus. Indeks diversitas dikategorikan sebagai menengah hingga tinggi (1,85 – 3,12), dengan nilai kemerataan yang rendah sampai tinggi (0,37 – 0,78), serta rendahnya tingkat indeks dominansi (0,05 – 0,24). Hal tersebut menunjukkan bahwa secara umum Perairan Pulau Putri masih dianggap memiliki kondisi lingkungan yang masih baik dan stabil untuk pertumbuhan foraminifera. Penurunan kestabilan lingkungan sedikit terjadi terutama di bagian timur laut penelitian yang memiliki tingkat polusi air tinggi. Hal ini mempengaruhi kelimpahan foraminifera yang ditunjukkan dengan menurunnya nilai indeks diversitas pada lokasi tersebut.*

***Kata Kunci:*** *Foraminifera bentik, analisis kuantitatif, Pulau Putri, Perairan Utara Batam*

## INTRODUCTION

Putri Island is located in the northern part of Batam, Riau Archipelago Province. It lies in the Singapore Strait, the outermost island directly adjacent to Singapore. The island is actually composed of three isles (Nongsa, Putri Besar, and Putri Kecil isles) that are visible during high tide, in contrast, during low tide. Meanwhile, the island will interconnect to form an elongated shape of Putri Island during low tide. As part of Malacca Strait, this area also has strong current conditions. It is influenced by the west winds and strong southeast winds that can generate waves (PPPGL, 2014). According to that survey, the current measurement conducted in May 2014 revealed that the current is dominated by a northeastward current. The current speed is high when approaching low tide (max speed 1.2 m/s at 3 m depth), in contrast, during minimum low tide the current speed is weak (min. speed 0.037 m/s at 3 m water depth) and changes direction.

Putri Island belongs to the Geological map of the Tanjungpinang Sheet, Sumatra (Kusnama et al., 1994). This area is located within the granite area of western Sumatra, part of the *Tin Belt of Sumatra* which extends from Thailand, the Malaysian Peninsula, Riau Islands, Singkep, Bangka and Belitung, and West Kalimantan (Batchelor, 1983). Because of the granite rock, the Riau archipelago including Putri Island and its surroundings are rich in placer minerals and rare earth element (REE) potency (Kusnama et al., 1994; Sukiyah et al., 2018). In Batam island, granite rock occupies particularly in the northern part, nearby Putri Island. It was deposited during Late Triassic and composed of feldspar, quartz, hornblende, and biotite as primary minerals, this granite in Batam island is classified as Nongsa Granite Pluton (Kusnama et al., 1994). Furthermore, sedimentological analysis including grain size analysis of the northern Batam waters surrounding Putri Island had been conducted by PPPGL (2014). The result revealed that this area is relatively dominated by coarse size fraction, particularly composed of three Quaternary sediment types. Including gravelly muddy sand on the western side of Putri and Batam Island, coarse sand – gravelly sand in the north of Putri Island, and sandy gravel on the eastern side, mainly gravelly sand and silty sand (Figure 1, Table 1). Moreover, sedimentological analysis indicated that Putri Island was composed of granite rocks that lead to a relatively steep morphology. Granite rock was deposited during Late Triassic, according to Kusnama et al. (1994), is observed on the coast side to form a cape morphology, remarkably at Putri Kecil Isle, which is surrounded by Quaternary gravel and boulders and in the northwest limestone reef was deposited (Figure 2). Putri Besar Isle is composed of a Tertiary conglomerate (Tanjung Kerotang Formation), while Nongsa Isle is occupied by Quaternary sand distributed surrounding the isle northwards to Putri Besar Isle (Hernawan et al., 2018).

Foraminifera is a single-celled microorganism and is generally found in brackish waters to the deep sea. Foraminifera is one of the particles in seabed sediments whose existence can reflect the ecological conditions in which they live. Based on their mode of life, foraminifera consists of benthic and planktonic foraminifera. Benthic foraminifera lives both freely and attaches themselves to the substrate at the waterbed, as the result benthic foraminifera are very sensitive to various environmental changes such as temperature, salinity, light penetration, depth, sediment type, oxygen content, etc. (Boltovskoy and Wright, 1976). In contrast, planktonic foraminifera lives within the water column, from the mixed layer to the

Table 1. Sediment type and water depth of sampling stations Putri Island Waters and surroundings, Riau Archipelago (PPPGL, 2014)

| Sample station | Depth (m) | Sediment type | Sample station | Depth (m) | Sediment type |
|---|---|---|---|---|---|
| PN-1401 | 10 | Gravel clay | PN-1920 | 17 | Sandy gravel |
| PN-1402 | 13 | Sandy clay | PN-1421 | 11 | Sand |
| PN-1403 | 10 | Silty sand | PN-1422 | 10 | Clay sand |
| PN-1404 | 9 | Silty clay | PN-1423 | 11 | Gravel sand |
| PN-1405 | 12 | Silty sand | PN-1424 | 30 | Silty sand |
| PN-1407 | 16 | Sandy clay | PN-1425 | 38 | Gravel sand |
| PN-1409 | 9 | Silty sand | PN-1426 | 42 | Clay sand |
| PN-1411 | 16 | Gravel sand | PN-1429 | 47 | Gravel sand |
| PN-1413 | 16 | Gravel silt | PN-1431 | 12 | Sandy gravel |
| PN-1414 | 13 | Clay gravel | PN-1432 | 32 | Gravel sand |
| PN-1415 | 15 | Sandy clay | PN-1433 | 44 | Gravel sand |
| PN-1416 | 25 | Sandy clay | PN-1435 | 50 | Silty sand |
| PN-1417 | 19 | Gravel clay | PN-1437 | 48 | Gravel sand |
| PN-1418 | 11 | Sandy clay | PN-1438 | 16 | Gravel sand |
| PN-1419 | 13 | Gravel sand | | | |

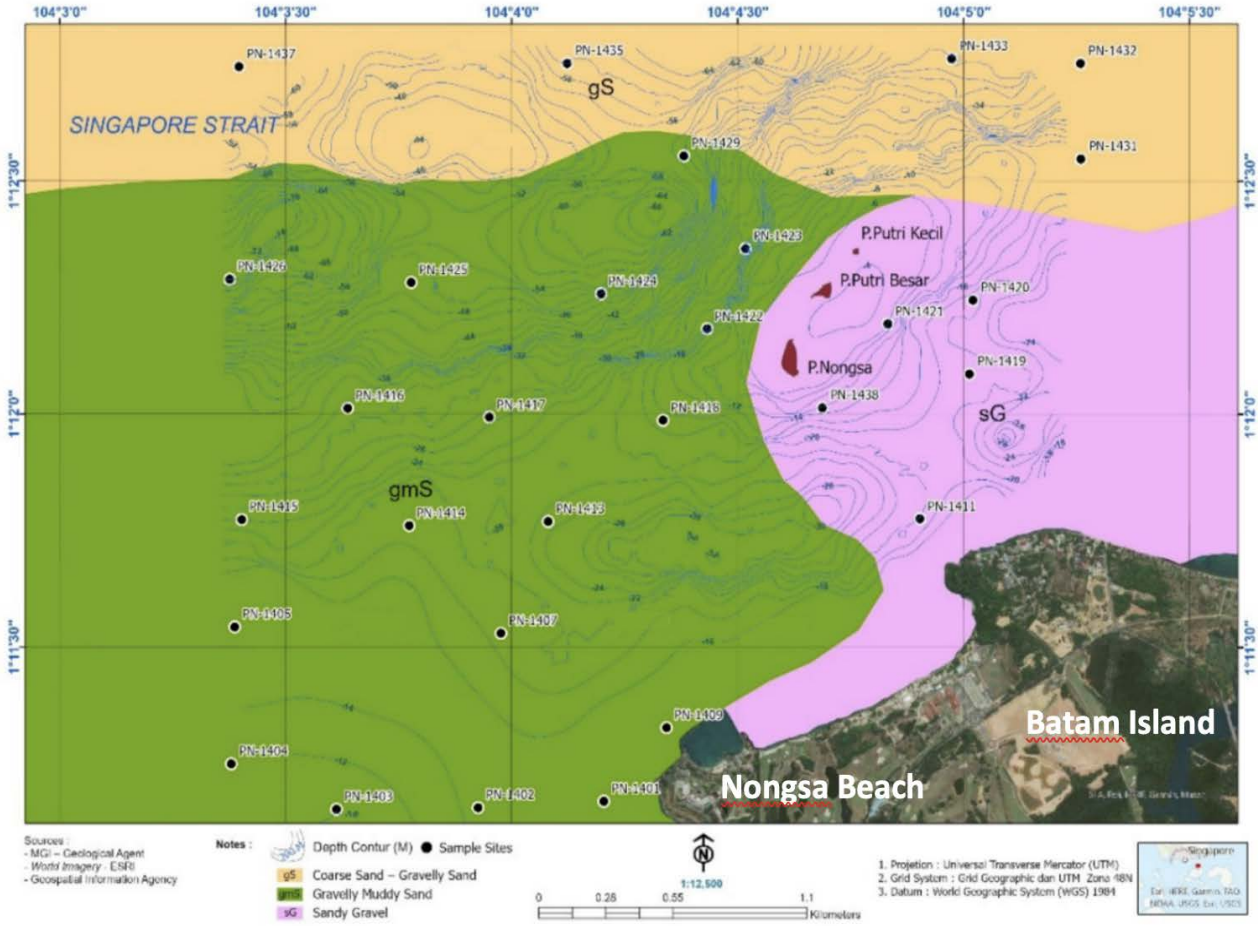


Figure 1. Distribution of surface sediment of the study area during high tide that indicate three isles within Putri Island (Nongsa, Putri Kecil and Putri Besar isles) (modified from PPPGL, 2014; Hernawan et al., 2018)

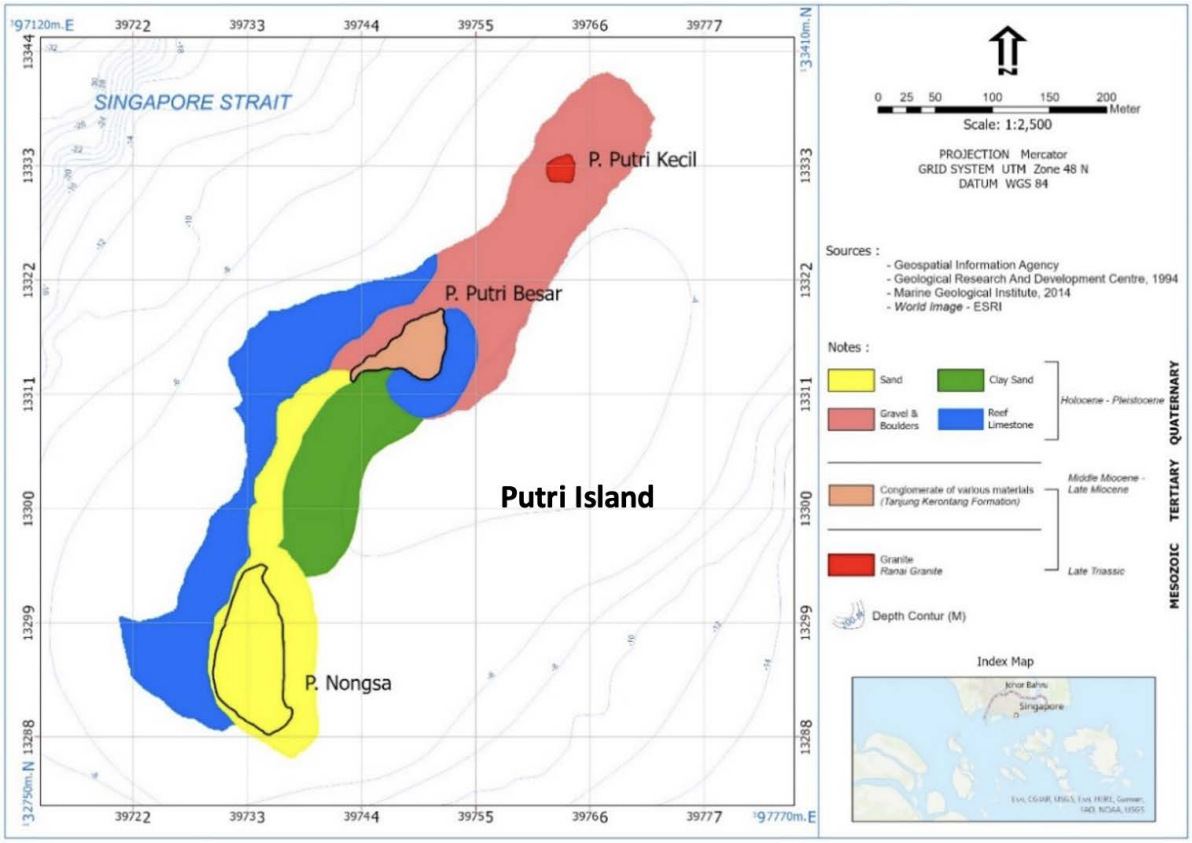


Figure 2. Geological map and bathymetry of Putri Island surrounding (modified from PPPGL, 2014; Hernawan et al., 2018)

deeper water column which is the thermocline and deep water layer. Both benthic and planktonic foraminifera is known as a potential indicator for environment, ecology, oceanography, and climatology both ancient and recent.

MGI conducted previous foraminifera studies of northern Batam and Bintan waters in 2005 and then analysed the surface sediments (Gustiantini and Usman, 2008). They observed that coral reef symbiont-bearing species dominated foraminifera in this area as an indication of relatively strong currents, such as *Amphistegina, Pseudorotalia, Eponides*, and *Asterorotalia.* Their results also diversity index value >3 suggested a good environmental condition. The waters surrounding Riau Archipelago has been known highly constituted by coral reefs habitat including off Tambelan Island, to the east of Putri Islands, and surrounds Natuna Islands in the northeast. Foraminiferal genera found in marine sediment from both locations also dominated by coral reef symbiont bearing, particularly *Amphistegina* and *Operculina* (Natsir et al., 2011; Junita et al., 2020). Marine geological and geophysical investigations in the waters of Putri Island, northern of Batam Island, were also conducted by MGI in 2014. Marine surface sediments have been studied for foraminifera related to coral reef growth by Divina et al. (2020) by calculating the FORAM (Foraminifera in Reef Assessment and Monitoring) Index. According to this author, the FORAM Index in this water ranges from 1.8-5.53, which indicates the aquatic environment is very conducive to not conducive to coral reef growth conditions. Therefore, this study aims to determine the abundance and distribution of benthic foraminifera in the waters of Putri Island, to enhance understanding about the biodiversity.

## DATA AND METHODS

This study utilised the abundance of foraminifera microfauna distribution data from 29 sea surface sediment samples taken from Putri Island waters, Riau Archipelago (Figure 1). The samples were collected by using a grab sampler and gravity corer in May 2014 by Marine Geological Institute (MGI). Preparation samples, foraminiferal picking, counting, and identification have been conducted by Divina et al. (2020). This previous study only discussed FORAM index (FI) analysis, while in this paper, we observed foraminiferal assemblages in more detail, and we conducted quantitative analysis including relative abundance (%), diversity index, evenness, and dominance indices.

**A**. Relative abundance (%) or foraminiferal percentage is determined by using the formula (Buzas and Hayek, 2005):

$$Pi = ni/N \times 100\% \quad 1)$$

ni = number of individuals within species in one sample

N = total specimen in one sample

**B.** Diversity index (H'), evenness index (E), and dominance index (D) were carried out to determine the level of species diversity in each sample.

Species diversity is the number of species in one assemblage or species-richness, defined as S (Gibson and Buzas, 1973; Pielou, 1979). The first publication argued that diversity is not determined only by the number of species but also takes into account species abundance, known as the diversity index. A measure of diversity that is most frequently used as a diversity index is the Shannon-Wiener information function, noted as H′ or H(S), defined as:

$$H' = -\sum_{i=1}^{n} Pi \,.\ln Pi) \quad 2)$$

$$Pi = \frac{ni}{N} \quad 3)$$

Where $Pi$ is the $i^{th}$ type proportion, and n is the $n^{th}$ individual (Gibson and Buzas, 1973; Hammer, 1999 – 2022; Pielou, 1979). The diversity index value is divided into 3 categories, are:

H' ≤ 1 = Low diversity
1 < H'≤ 3 = Moderate diversity
H' ≥ 3 = high diversity
(Odum, 1971 *op cit* Ulfah et al., 2019)

H(S) is maximum (Maximum diversity) when all S is equally distributed (a measure of evenness or equitability E value is 1), in contrast, the E value will be less than 1 when all species are not equally distributed (Buzas and Hayek, 1996). The Evenness index is the distribution of species abundance within a community, Buzas and Gibson (1969) defined E as:

Evenness index: $E = \frac{e^H}{S}$ 4)

e is the base of natural logarithms. Krebs (1989, *op cit* Ulfah et al., 2019) divided the evenness index into 3 groups are:

0 < E ≤ 0.5 = Depressed community
0.5 <E ≤ 0.75 = Unstable community
0.75 <E ≤ 1 = Stable community

A community with a single dominant species tends to have a decreased diversity index (Gibson and Buzas, 1973). At such community dominance index value will be 1, a lower value suggests that all species are equally present (Hammer, 1999 – 2022). Dominance is the opposite of evenness (Hayek and Buzas, 2013). The dominance index is calculated by the formula:

Dominance Index: $D = (\frac{\mathrm{ni}}{\mathrm{N}})^2$ 5)

With categories (Odum, 1971 *op cit* Ulfah et al., 2019):

0 < C < 0,5 = Low Dominance.
0,5< C ≤ 0,75 = Moderate Dominance.
0,75< C ≤ 1,0 = High Dominance.

The calculation of the diversity index (H), evenness index (E), and dominance index (D) was carried out using Past 4.11 (Paleontological Statistics Ver. 4.11), a software from Hammer (1999-2022) and Hammer et al. (2001), can be downloaded freely at https://www.nhm.uio.no/english/research/resources/past/.

## RESULTS

Foraminifera was found in all 29 sediment samples from off Putri Island composed of benthic foraminifera with various types and abundances. In general, the preservation of the foraminiferal shells was found in good condition, however, some specimens were also found in poor shell condition e.g. broken chamber, not intact/ damaged and grey to blackish. The number of foraminifera found in sediment samples varied from very rare (one specimen) to very abundant (>25 specimens). In total, foraminifera consists of 62 species belonging to 31 genera. The highest number of species was found at PN-1411 in the south of Putri Islands with 38 species, and the lowest abundant with only contained of 12 species are found at stations PN-1433 and PN-1435, located in the northernmost of the study area, within Singapore Strait. The benthic foraminifera consists of 40 species belongs to 22 genera of Suborder Rotaliina, 16 species from five genera of Suborder Miliolina, and six species from four genera of Suborder Textulariina. Several genera that are predominant in the study area, are (Figure 3):

- *Amphistegina* is the most abundant genus found in the research area with an average percentage of 14.26%, It has fairly good to very poor shell preservation (shells found in damaged conditions). This genus is found in almost all locations except at PN-1426, PN-1435, and PN-1437, which are located in the most northwest of the study area (the outer most position, within Singapore Strait), among area with the deepest water depth compared to the other stations (water depth > 38 m) (Figure 4a). At sandy gravel area (in the east side of Putri Island) *Amphistegina* found very abundant. *Amphistegina radiata* is found abundantly and distributed widely in the study area compared to *Amphistegina lessonii*, and *Amphistegina* sp. This species is also found at PN-1429 and PN-1433 where the other two species are absent.
- *Discorbinella* is identified in few to abundant quantities and it is more prevalent in the southwest part of Putri Island and towards the open sea which composed by gravelly muddy sand (Figure 4b). In contrast to *Amphistegina,* at the east side of Putri Island that characterized by sandy gravel, this genus assemblage is low (< 5%). This genus is recognized from 25 sediment samples with an average abundance of 7.11%. This genus is found the most abundant at PN-1403, PN-1418, and PN-1414, with assemblage 20.7%, 19.8%, and 21.2%, respectively. This genus is absent at three locations are PN-1429 and PN-1432 at the north area, and PN-1438, to the south of Nongsa Isle.
- *Elphidium* is recognized with good shell preservation conditions with average abundance is 14.11%. It is contained at almost all samples except at PN-1437 in the northwest part (Figure 4c). This genus consists of six species, specifically *Elphidium craticulatum, Elphidium hispidulum, Elphidium crispum, Elphidium haagensis, Elphidium jenseni*, and *Elphidium reticulosum*. They are found mostly abundant to very abundant, particularly at PN-1422 station in the west side of Nongsa Isle with a percentage of 34.81%. Similar to *Amphistegina,* this genus assemblage decreases at the northwestern part of the study area (PN-1437 and PN-1436), and found very abundant to the east of Putri Island which composed of sandy gravel sediment.
- *Operculina* has an abundance percentage of 4.89% (on average) and is found in 25 sediment samples with a few to very abundant, mostly found in common quantity (6-10%) (Figure 4d). The most abundant percentage of this genus particularly at PN-1407 with percentage of 29.4%. Abundant assemblage particularly at the south part of the study, nearby Batam Island (Nongsa Beach) and in the middle part of the study area, nearby Putri Island, which characterized by coral reef ecosystem. It is absent at PN-1432 and PN-1433 at the northeastern area, and at PN-1426 in the western part. The condition of *Operculina* tests found fairly good to be very poor preservation.
- *Ammonia* has an average abundance of 4.24% and is distributed unevenly. This genus occurs abundantly at stations PN-1416, PN-1418, and PN-1435. In general, this genus is more abundant in the area of gravelly muddy sand compared to coarser sediment, primarily sandy gravel of eastern part of Putri Island which very low to absent abundance (Figure 4e).
- *Rotalidium* especially *Rotalidium annectens* is identified in all locations except at PN-1402 and PN-1405, located nearby Nongsa Beach, in the southern part of the study area (Figure 4f). This southern area is considered have lower abundance of this genus. In contrast to *Amphistegina* and *Elphidium* distribution, this species is very abundant in the west-northwest of Putri Island (water depth 40 m), particularly at stations PN-1426, PN-1429, PN-1435, and PN-1437. However, similar to these two genera, *Rotalidium* is also found very abundant within sandy gravel sediment, to the east of Putri Island.

- The average abundance of *Quinqueloculina* is 11.38%. This genus occupies every location in moderate to abundant quantities and has fairly good shell preservation conditions (Figure 4g). The highest abundance of this genus is at PN-1405 with a percentage of 40.3%. Similar to *Amphistegina* and *Elphidium,* this genus also demonstrates very high abundance within sandy gravel sediment at the east side of Putri Island.
- *Asterorotalia* is identified in 23 sediment samples, with very low percentage in all locations (2.21% in average). It is distributed evenly, found the most abundant at PN-1424 with percentage 19.7%. It is also absent at PN-1433 in the northeast of the study area. Another area that is absent of this genus mostly nearby Putri Island, particularly at the east side which characterized by sandy gravel (Figure 4h).
- *Textularia* is found in 26 sediment samples from few to abundant, with an average abundance of 7.6%. It is more distributed towards the southwest part of Putri Island, especially at PN-1414 which composed of 70 specimens.
- *Eponides* occur in 24 sediment samples, from few to very abundant quantities (6.27% in average). This genus was found the most abundant at PN-1415 station with abundance of 16%.

Very few species were found only in certain locations with very low abundance (< 1%), such as *Hauerina pacifica, Cymbaloporetta* sp., *Rotalia soldanii, Lagena sulcata*, and *Poroeponides* sp. The distribution of benthic foraminifera found in the research area is presented in Table 2.

The diversity index values in all sediment samples from the waters of Putri Island are varied between 1.85 – 3.12. High index diversity value (H' > 3) was only found at PN-1413 station, in the southwest of Putri Island. It indicates high species diversity and high stability of community structure, while a low diversity index value (1.85) was only found at station PN-1433 in the northeast of the island. Most of the location has diversity index value between 1 < H' < 3, suggesting moderate species diversity and moderate stability of community structure. This value might be related to water conditions that are still fairly good and quite stable for the growth of an organism including foraminifera (Adiwilaga et al. 2012). The evenness index (E') has a value ranging between 0.37-0.78. The evenness index value lower than 0.4 (small population evenness level) was only found at station PN-1409, which indicates the dominance of a particular species. The other stations generally have moderate to high levels of population evenness (E' > 0, 4), this indicates that there are no or few predominant foraminiferal species (Insafitri, 2010). The dominance index has a range of values between 0.05-0.24 which belongs to the low category, suggesting there are no/very few foraminifera species that are dominant (Bawol et al. 2017). Foraminiferal index chart in Putri Island is displayed in Figure 5.


Figure 3. Several predominant genera found in the marine sediment surrounding Putri Island: 1) *Amphistegina;* 2) *Asterorotalia;* 3) and 4) *Elphidium;* 5) *Discorbinella;* 6) *Ammonia,* 7) *Eponides;* 8) *Operculina;* 9) *Rotalidium;* 10) *Quinqueloculina.*

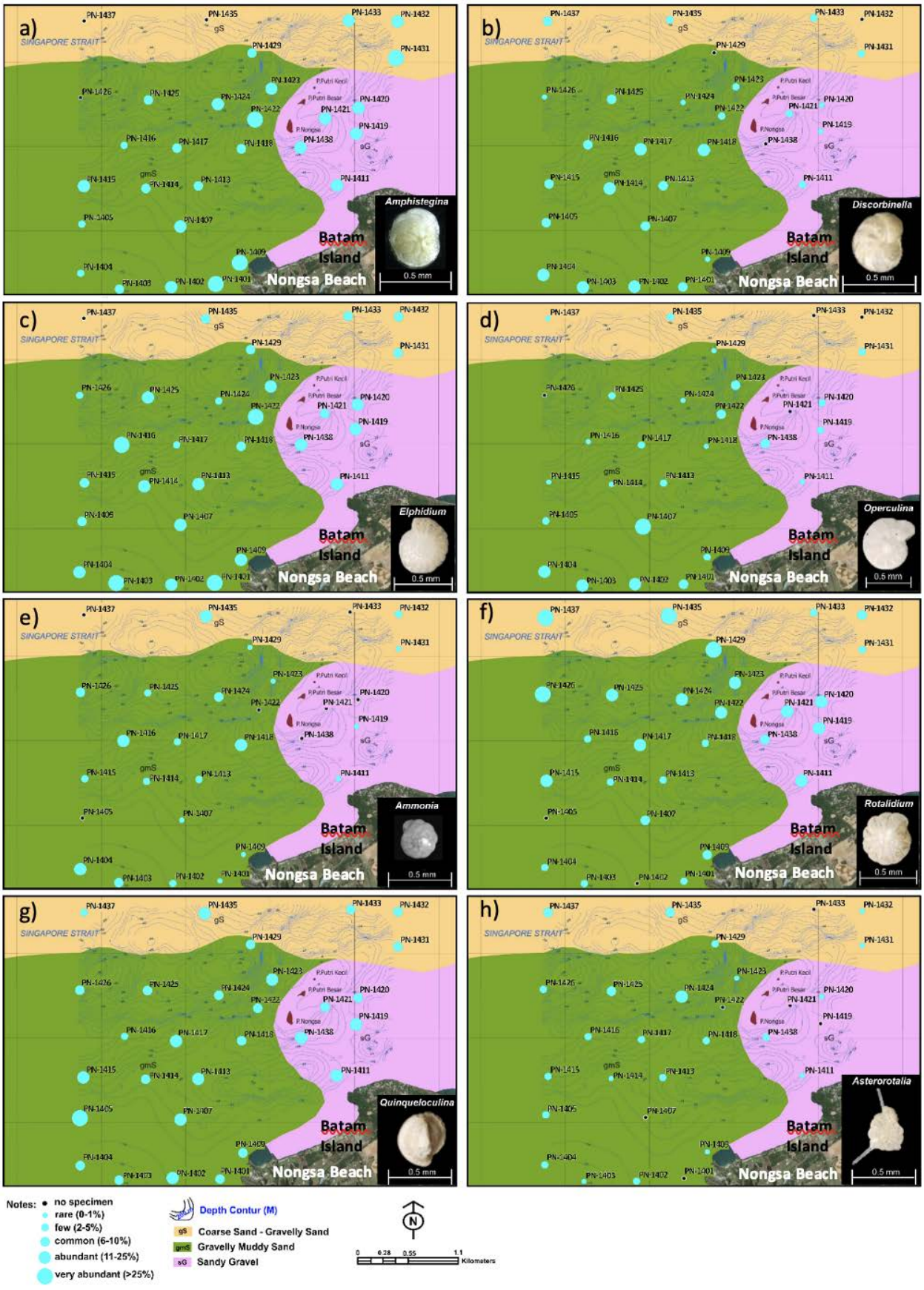


Figure 4. Spatial distribution of several genera of foraminifera in the marine surrounding Putri Island

Table 2. Distribution and abundance of foraminifera in the marine sediment off Putri Island, Riau Archipelago

| No | | Number of specimens in sediment sample (%) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Sample Number** | **PN-1404** | **PN-1409** | **PN-1401** | **PN-1403** | **PN-1422** | **PN-1418** | **PN-1421** | **PN-1423** | **PN-1405** | **PN-1431** | **PN-1402** | **PN-1414** | **PN-1419** | **PN-1415** | **PN-1407** | **PN-1411** | **PN-1413** | **PN-1438** | **PN-1420** | **PN-1417** | **PN-1416** | **PN-1424** | **PN-1432** | **PN-1425** | **PN-1426** | **PN-1433** | **PN-1429** | **PN-1437** | **PN-1435** | **Ave-rage** |
| | **Depth(m)** | **9** | **9** | **10** | **10** | **10** | **11** | **11** | **11** | **12** | **12** | **13** | **13** | **13** | **15** | **16** | **16** | **16** | **16** | **17** | **19** | **25** | **30** | **32** | **38** | **42** | **44** | **47** | **48** | **50** | |
| | **Species Name** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | *Ammonia beccarii* | | | | | | | | | | | | | | | | | 1.0 | | | 0.4 | | | | | 6.7 | | | | 3.2 | 0.39 |
| 2 | *Ammonia convexa* | 22.4 | 1.4 | 1.8 | | | 13.7 | | | | 0.3 | 3.5 | | 0.7 | 2.2 | 0.6 | 0.4 | 0.3 | | | 0.8 | 17.6 | 6.7 | 1.9 | | | | 0.9 | | 9.7 | 2.92 |
| 3 | *Ammonia* sp. | 1.2 | | | 5.8 | | 5.7 | | 1.3 | | | | 2.4 | 1.0 | | | 1.2 | 1.0 | | | 1.1 | 3.4 | | | 2.6 | | | | | | 0.92 |
| 4 | *Amphistegina lessonii* | | | | | | | 0.6 | | | 4.5 | | | 0.3 | | | | | | 4.3 | 1.1 | | | 0.5 | | | | | | | 0.39 |
| 5 | *Amphistegina radiata* | 2.4 | 40.2 | 27.6 | 5.1 | 28.1 | 9.3 | 21.7 | 12.9 | 3.5 | 28.7 | 14.2 | 10.6 | 15.6 | 12.0 | 9.2 | 21.6 | 6.6 | 18.4 | 19.0 | 6.4 | 2.6 | 20.2 | 21.9 | 7.4 | | 18.8 | 7.8 | | | 13.50 |
| 6 | *Amphistegina* sp. | 0.8 | 0.4 | 1.8 | 1.4 | 0.4 | | | | | | 0.8 | | 2.0 | | 1.8 | 0.8 | | | | | | | | | | | | | | 0.35 |
| 7 | *Asterorotalia trispinosa* | 2.4 | 0.4 | | 1.8 | | 3.4 | | 0.6 | 3.5 | 0.7 | 2.4 | 0.8 | | 2.7 | | 0.8 | 4.5 | 2.0 | 0.9 | 4.9 | 2.6 | 19.7 | 1.4 | 6.3 | 4.0 | | 3.4 | 6.5 | 6.5 | 2.21 |
| 8 | *Bolivina midwayensis* | 0.8 | | 0.7 | 1.4 | | 3.1 | 0.6 | 0.3 | 1.8 | 0.7 | 1.2 | 1.6 | 0.3 | 1.3 | 0.9 | 0.4 | 1.4 | | | | | 5.5 | | 1.8 | | | | | | | 0.82 |
| 9 | *Cibicides pseudolobatulus* | | 0.4 | | | | | | | | | | | | | | 0.4 | | | | | | | | | | | | | | 0.03 |
| 10 | *Cibicides* sp. | | 0.7 | | | | | | | | 1.0 | | | | | | | | | 3.4 | | 0.4 | | 0.5 | | | | | | | 0.21 |
| 11 | *Cibicidoides pseudoungeriana* | | | | | | 0.5 | | | | | | | | 0.4 | | 1.9 | 0.3 | | | 1.5 | 2.6 | | | | | | | | | 0.25 |
| 12 | *Clavulina pacifica* | | 1.1 | 1.1 | | | | 0.6 | 1.9 | | 0.7 | | | 0.7 | | | 1.9 | 0.3 | | 1.7 | | | | | 0.4 | | | | | | 0.36 |
| 13 | *Clavulinoides indiscretus* | | 0.7 | | | 1.1 | 0.3 | | | | | | | 0.3 | | | 1.2 | | | | | | | | 0.4 | | | | | | 0.13 |
| 14 | *Cymbaloporetta* sp | | 0.4 | | | | | 0.6 | | | | | | | | | | | | | | | | | | | | | | | 0.03 |
| 15 | *Discorbinella bertheloti* | 14.4 | 1.4 | 8.1 | 20.7 | 1.9 | 19.8 | 3.7 | 3.6 | 10.5 | 2.4 | 12.2 | 21.2 | 1.7 | 7.6 | 8.3 | 4.2 | 10.1 | | 0.9 | 13.2 | 9.01 | 0.4 | | 10.3 | 1.3 | 4.2 | | 10.8 | 3.2 | 7.06 |
| 16 | *Discorbinella* sp. | | | | | | | | | | | | | | | | 0.4 | | | | 0.8 | | | | | | | | | | 0.04 |
| 17 | *Elphidium craticulatum* | 5.2 | 3.9 | 4.9 | 5.4 | 15.6 | 0.5 | 6.2 | 9.7 | 5.3 | 4.2 | 7.1 | 2.7 | 3.3 | 4 | 6.1 | 7.7 | 3.1 | 6.1 | 4.3 | 1.5 | 1.3 | 0.4 | 6.2 | 7,0 | | 4.2 | 3.4 | | | 4.46 |
| 18 | *Elphidium crispum* | 0.8 | 0.4 | 4.9 | | | | 0.6 | | | | 0.8 | | 10 | | 1.2 | | 1.4 | | | | 8.6 | | 1.0 | | | | | | | 1.02 |
| 19 | *Elphidium haagensis* | 0.4 | | | | | | | | | | | 2.4 | | 0.4 | | | 0.3 | | | | 0.9 | | | | | | | | | 0.15 |
| 20 | *Elphidium hispidulum* | 13.6 | 7.8 | 8.5 | 13.04 | 19.3 | 3.6 | 3.1 | 9.03 | 1.8 | 2.8 | 4.7 | 3.1 | 5.6 | 2.7 | 9.5 | 3.5 | 6.9 | 10.2 | 6.9 | 1.5 | 15.5 | 0.4 | 2.9 | 8.5 | 5.3 | 2.1 | 5.2 | | 9.7 | 6.43 |
| 21 | *Elphidium jenseni* | | | 7.4 | | | 3.9 | | | | | 3.9 | 2.4 | | 3.6 | 4.3 | 0.8 | | | | 1.1 | | 0.4 | 0.5 | | | | | | | | 0.97 |

| No | Sample Number | Number of specimens in sediment sample (%) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | PN-1404 | PN-1409 | PN-1401 | PN-1403 | PN-1422 | PN-1418 | PN-1421 | PN-1423 | PN-1405 | PN-1431 | PN-1402 | PN-1414 | PN-1419 | PN-1415 | PN-1407 | PN-1411 | PN-1413 | PN-1438 | PN-1420 | PN-1417 | PN-1416 | PN-1424 | PN-1432 | PN-1425 | PN-1426 | PN-1433 | PN-1429 | PN-1437 | PN-1435 | Ave-rage |
| | **Depth(m)** | **9** | **9** | **10** | **10** | **10** | **11** | **11** | **11** | **12** | **12** | **13** | **13** | **13** | **15** | **16** | **16** | **16** | **16** | **17** | **19** | **25** | **30** | **32** | **38** | **42** | **44** | **47** | **48** | **50** | |
| | **Species Name** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22 | *Elphidium reticulosum* | 4.8 | 0.4 | | 12.7 | | | | | | | | 1.6 | | | | | 3.1 | | | | 5.6 | 0.8 | | 2.6 | | | | | | 1.08 |
| 23 | *Eponides cribrorepandus* | | 3.9 | 1.1 | | 1.5 | 0.5 | 19.3 | 8.1 | 8.8 | 6.9 | | 1.6 | 4.7 | 16.4 | | 3.5 | 2.8 | 20.4 | 9.5 | 6.0 | 1.3 | 2.8 | 11 | 5.1 | 8 | 2.1 | 13.8 | 18.3 | | 6.10 |
| 24 | *Eponides repandus* | | | | | | 2.6 | | | | | | | | | | | | | | | 0.9 | | | 1.1 | | | | | | 0.16 |
| 25 | *Glandulina ovula* | | 0.4 | 0.4 | | | | | 0.3 | | 0.3 | | | | | | 1.5 | 0.3 | | | 0.8 | | | | | | | | | | 0.14 |
| 26 | *Hauerina pacifica* | | | 0.4 | | | | | | | | 0.4 | | | | | | | | | | | | | | | | | | | 0.03 |
| 27 | *Lagena sulcata* | | | 0.4 | | | | | | | | 0.4 | | | | | | 0.3 | | | | | 0.4 | | | | | | | | 0.05 |
| 28 | *Neoconorbina terquemi* | 4 | 2.1 | 0.7 | 7.2 | 0.4 | 3.1 | 1.2 | | | 1.4 | 2.0 | | 1.3 | | 0.6 | 0.4 | 0.7 | | | 0.4 | | 2.0 | 1.4 | | 1.3 | | | | | 1.04 |
| 29 | *Neorotalia calcar* | | | | | | | | | | | | | 0.7 | | | | | | | | | | 6.7 | | | | | | | 0.25 |
| 30 | *Operculina ammonoides* | 8 | 5.0 | 7.4 | 12.3 | 8.5 | 1.3 | | 3.2 | 1.8 | 2.1 | 5.1 | 0.4 | 5.6 | 1.8 | 18.7 | 1.5 | 3.1 | | 2.6 | 2.3 | 0.9 | 0.8 | | 5.1 | | | | 1.1 | 3.2 | 3.51 |
| 31 | *Operculina* sp. | | 0.4 | 1.8 | | | | | | 1.8 | | 1.6 | | | | 0.3 | | | | | | | | | 0.4 | | | | | | 0.21 |
| 32 | *Operculina subgranulosa* | 6.4 | | | | | | | 4.2 | | | 5.9 | | | | 10.4 | | | 6.1 | | | | | | | | | 0.9 | | | 1.17 |
| 33 | *Pararotalia armata* | | | 0.4 | | | | 2.5 | 2.3 | | 3.1 | | 0.8 | 0.7 | | | 1.2 | 0.7 | | 1.7 | 1.5 | 0.9 | 1.2 | | | | | 1.7 | | | 0.64 |
| 34 | *Pararotalia nipponica* | | | | | | 0.8 | 0.6 | 0.3 | 3.5 | | 2.0 | | | 0.4 | | 0.4 | 1.4 | | | 0.8 | 1.3 | 2.0 | | 2.6 | 4 | | 0.9 | 3.2 | | 0.83 |
| 35 | *Pararotalia* sp. | 0.4 | | | | | 0.5 | 1.2 | | | 0.3 | | | | | | | | | | | 0.9 | | 5.7 | | | 8.3 | | | 6.5 | 0.82 |
| 36 | *Pararotalia venusta* | | | | | | 0.8 | 3.7 | 1.0 | 3.5 | 7.6 | | 0.4 | 0.3 | | | | | 4.1 | 3.4 | 9.4 | | | 12.4 | | | 43.8 | 0.9 | | | 3.15 |
| 37 | *Poroeponides* sp. | | | | | 0.4 | | | | | | | | | | | | | | | 0.8 | | | | 0.4 | | | | | | 0.05 |
| 38 | *Pseudorotalia* sp. | | 0.4 | | | | 4.6 | | | | | 2.8 | 6.7 | | 0.9 | | 0.4 | 11.8 | | | | 3 | 2.0 | | | | | | | | 1.12 |
| 39 | *Pyrgo denticulata* | | 0.4 | | | | | | | | | | | 0.7 | | | 1.2 | | | | 0.8 | | | | | | | | | | 0.10 |
| 40 | *Pyrgo* sp. | | 0.4 | 0.4 | | | | | | | | 0.4 | | | | | 0.4 | 0.3 | 4.1 | | | | | | | | | 0.9 | | | 0.23 |
| 41 | *Quinqueloculina agglutinans* | | | | | | 1.3 | 0.6 | 1.6 | 3.5 | 0.7 | 2.8 | 1.6 | | 1.8 | | 1.2 | 0.3 | | | 1.5 | 0.4 | 0.8 | | 0.7 | | | 6.0 | | | 0.85 |
| 42 | *Quinqueloculina bradyana* | 0.8 | 1.1 | 2.8 | 1.8 | 4.4 | | 1.9 | 3.9 | | 4.5 | 2.8 | 1.6 | 4.3 | 6.7 | 2.1 | 1.9 | 1.0 | | 8.6 | | 0.4 | | | 3.3 | 4 | | 4.3 | 4.3 | 12.9 | 2.74 |
| 43 | *Quinqueloculina laevigata* | 0.4 | | 1.4 | | | 1.8 | | | | 0.3 | | | | | | 0.4 | 1.0 | | | 0.4 | 0.9 | | | | | | | | | 0.23 |
| 44 | *Quinqueloculina porterensis* | | 5.3 | | | 1.1 | 3.6 | 3.1 | 3.6 | 3.5 | 3.5 | 2.4 | 3.9 | 3.3 | 3.6 | 1.8 | 5.4 | 3.5 | 4.1 | | 8.7 | 2.1 | 4.7 | 1.0 | 3.7 | | | | | | 2.47 |

| No | Sample Number | Number of specimens in sediment sample (%) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | PN-1404 | PN-1409 | PN-1401 | PN-1403 | PN-1422 | PN-1418 | PN-1421 | PN-1423 | PN-1405 | PN-1431 | PN-1402 | PN-1414 | PN-1419 | PN-1415 | PN-1407 | PN-1411 | PN-1413 | PN-1438 | PN-1420 | PN-1417 | PN-1416 | PN-1424 | PN-1432 | PN-1425 | PN-1426 | PN-1433 | PN-1429 | PN-1437 | PN-1435 | Ave-rage |
| | **Depth(m)** | **9** | **9** | **10** | **10** | **10** | **11** | **11** | **11** | **12** | **12** | **13** | **13** | **13** | **15** | **16** | **16** | **16** | **16** | **17** | **19** | **25** | **30** | **32** | **38** | **42** | **44** | **47** | **48** | **50** | |
| | **Species Name** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 45 | *Quinqueloculina pseudoreticulata* | | | 0.4 | | | | 1.2 | | 26.3 | | | | | | | 3.5 | 3.1 | | | 3.8 | | | 2.9 | | 2.7 | 2.1 | | | | 1.58 |
| 46 | *Quinqueloculina sp.1* | 4.4 | | | 2.5 | | 2.8 | | 3.9 | | | 2.0 | 3.5 | 4,0 | 2.7 | 5.2 | 2.3 | 3.5 | 12.2 | | | | 2.8 | 3.3 | | | 6.3 | | | | 2.11 |
| 47 | *Quinqueloculina sp.2* | 1.6 | 0.7 | | | 1.1 | | | 0.3 | | | | | | | 0.6 | | | | | | | | | | 1.3 | | | | | 0.20 |
| 48 | *Quinqueloculina vulgaris* | | 2.5 | 4.2 | 5.4 | 0.4 | | 2.5 | 1.0 | 7.0 | 1.7 | 6.7 | | | | 2.8 | | | | | | | | | | | | | | | 1.18 |
| 49 | *Rosalina bradyi* | | | | | | | | | | | | | 0.3 | | | 0.8 | | | | | | | | | | | | | | 0.04 |
| 50 | *Rosalina globularis* | | | | | | 3.4 | 0.6 | 0.3 | | 0.3 | | | | 2.2 | | 0.4 | | | | | | | | | | 2.1 | | | | 0.32 |
| 51 | *Rotalia soldanii* | | | | | | | | | | | | | | | | | | | | | 1.3 | | | | | | | | | 0.04 |
| 52 | *Rotalidium annectens* | 3.2 | 6.8 | 5.7 | 2.9 | 14.1 | 2.6 | 13.7 | 17.7 | | 3.1 | | 3.1 | 11 | 11.6 | 7.1 | 12.7 | 3.8 | 8.2 | 18.1 | 11.7 | 4.7 | 11.1 | 6.7 | 12.5 | 37.3 | 4.2 | 34.5 | 33.3 | 35.5 | 11.61 |
| 53 | *Siphogenerina raphanus* | | 0.7 | | | | 0.8 | 0.6 | 1.3 | | 1.0 | 0.4 | 0.4 | 1.0 | | | 0.4 | | | | 0.8 | | 0.4 | | | | | | 1.1 | | 0.30 |
| 54 | *Siphotextularia concava* | 0.4 | | | 0.4 | 0.7 | | | | 3.5 | 1.4 | | | 2.3 | | | | | | | | | | 1.4 | 10.3 | 2.7 | | 2.6 | | 3.2 | 1.00 |
| 55 | *Spiroloculina corrugata* | | 0.4 | 0.7 | | | | 1.9 | 0.6 | | | 1.2 | | | | 0.3 | | 0.7 | | | 1.5 | | | | 1.8 | | | | 2.2 | | 0.39 |
| 56 | *Spiroloculina rugosa* | | | | | | 0.3 | | | | 0.7 | | | | 1.3 | 0.3 | | 1.0 | | | 1.1 | 0.4 | 0.8 | 0.5 | | | | | 3.2 | | 0.33 |
| 57 | *Textularia agglutinans* | | 4.6 | 2.8 | | | 3.6 | 1.2 | 2.9 | | | 10.6 | 23.5 | | 0.9 | 7.1 | 4.6 | 8.3 | | | | 6.4 | 15.4 | | | | | | | | 3.17 |
| 58 | *Textularia conica* | | | | | | | 0.6 | 0.6 | | 0.3 | | 0.4 | 0.7 | 0.4 | | | | 2.0 | | | | | | | 1.3 | | | | | 0.22 |
| 59 | *Textularia sp.* | | 5.0 | 0.7 | | | 1.5 | 2.5 | 3.2 | 10.5 | 8.3 | | 3.5 | 7.3 | 6.7 | 0.3 | 6.2 | 2.1 | 2.0 | 1.7 | 7.5 | 3.9 | 4.0 | 5.2 | 5.5 | 10.7 | 2.1 | 9.5 | 8.6 | 3.2 | 4.20 |
| 60 | *Triloculina insignis* | | 0.7 | | | 1.1 | 0.5 | 1.2 | 0.3 | | 0.3 | | | 1.0 | 0.9 | 0.3 | 2.3 | | | 0.9 | 1.5 | | 8.7 | | | 1.3 | | 0.9 | | | 0.76 |
| 61 | *Triloculina sp.* | 1.2 | | 1.8 | | | | 1.9 | | | 5.2 | | | 0.3 | 3.6 | | | 6.6 | | 11.2 | 2.6 | | 3.6 | 5.2 | 0.4 | 4.0 | | 0.9 | 6.5 | 3.2 | 2.00 |
| 62 | *Triloculina tricarinata* | | | | | | | | | | 0.7 | | | 9.0 | 1.3 | | 0.4 | 2.8 | | | 1.9 | 0.4 | | | | 4.0 | | 1.7 | 1.1 | | 0.80 |
| Number of species | | 23 | 32 | 27 | 16 | 17 | 30 | 29 | 29 | 17 | 32 | 26 | 24 | 31 | 27 | 24 | 38 | 36 | 13 | 18 | 33 | 29 | 26 | 22 | 24 | 17 | 12 | 19 | 13 | 12 | |
| Number of genus | | 13 | 21 | 19 | 11 | 12 | 20 | 16 | 18 | 11 | 21 | 16 | 14 | 20 | 17 | 12 | 23 | 21 | 10 | 13 | 19 | 17 | 18 | 15 | 18 | 12 | 9 | 13 | 11 | 11 | |

## DISCUSSIONS

In general, the preservation conditions of foraminifera shells found in the waters of Putri Island are still in good condition. However, there are some specimens identified in damaged shell conditions. The abnormal shape of the shell can be possibly due to environmental influences or local water conditions that affect organisms on the seabed including foraminifera as a component of sediment particles.

The waters off Putri Island as the research area is a shallow water environment with water depths between 9 and 50 meters and coral reef ecosystems occupy part of the area (along the west side of Putri Island) (Figure 2). The benthic foraminifera found at each station has different compositions of abundance and species. The highest number of foraminifera was found at PN-1423 station with water depths of 11 m, located in the northwest part. The highest abundance of foraminifera is also found at PN-1407 (water depth 16 m), located in the southwest of Putri Island. The sediment type of these two locations is dominated by gravel sand and sandy clay sediments (Table 1). In general, benthic foraminifera are more prevalent in sediments dominated by sand. According to Susanto (2000), the basic substrate type also determines the quantities and species of benthic organisms in the water. Seabed sediments consisting of coarse sand particles are considered more conducive to foraminifera's life since they can reduce the rate of hydrodynamic pressure in these waters.

Ocean parameters such as current velocity will also affect the distribution of the benthic foraminifera. Although the average current velocity in the study area is classified as low-medium with an average speed of 0.356 m/s, however, in a certain area the current velocity can be relatively strong to reach a maximum velocity of 0.997 m/s (PPPGL, 2014). With these water conditions, the benthic foraminifera contained in sediments in the research area are relatively dominated by *Elphidium* and *Quinqueloculina* species which are indeed known to prefer live at a shallow environmental characteristic with moderate to high current levels (e.g. Woo et al., 1997).

*Elphidium* was found abundantly in almost all stations excluding PN-1437. According to Gustiantini and Usman (2018), several species of *Elphidium* characterize shallow water with relatively high current energy. *Elphidium craticulatum* and *Elphidium crispum* have a wide distribution from the coast to the middle neritic (Boltovskoy & Wright, 1976). *Elphidium* which belongs to the opportunistic foraminifera group has high adaptability and can survive in depressed environmental conditions. Thus this genus can live in various conditions because the carrying capacity of the environment for its life can be neglected. *Quinqueloculina* was also found abundant in all stations. *Quinqueloculina* is an inhabitant of open marine environments with moderate to high current velocities, as well as mud and sand sediments (Boltovskoy & Wright, 1976; Yassini & Jones, 1995; Rositasari & Rahayuningsih, 2000). Albani (1979) stated that several species of *Quinqueloculina* genus are inhabitants of shallow waters. The high current energy in the research area can also be suggested by the occurrence of broken/incomplete foraminiferal tests due to current movement, as revealed in the study of Gustiantini and Usman (2008).

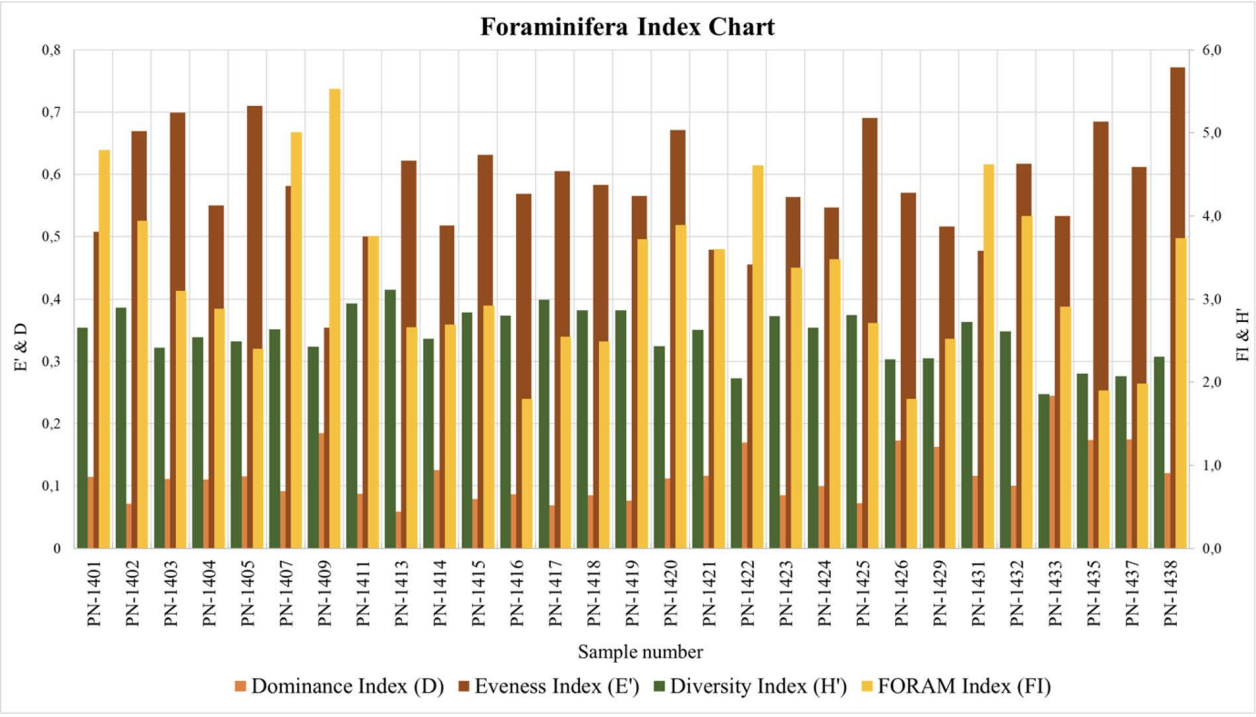


Figure 5. Foraminiferal indices chart in the marine surrounding Putri Island

In the southwestern part of the research area, the presence of coral reefs plays a very important role in the foraminiferal distribution. Symbiont-bearing *Amphistegina* species are found to be very abundant in this part area. *Amphistegina* has a wide distribution in coral reef waters and other shallow waters dominated by carbonate material. The genus *Amphistegina* can provide information related to waters with good coral reef conditions since it has a significant role as a calcium carbonate (CaCO3) producer in sediments (Hallock et al., 1995). Foraminiferal species such as *Amphistegina* which have thick shells, strong ornamentation, biconvex shape, and fusiform are mostly found in sand and gravel sediment types (Boltovskoy & Wright, 1976). *Amphistegina* was found at 26 stations that were more widely distributed to the east, south, and southwest of the research area with sand and gravel sediment types. This may indicate that the environment in the eastern to the southwestern part of Putri Island waters are classified as conducive to the growth of coral reefs. This result is in accordance with the FORAM Index values of the waters studied by Divina et al. (2020). According to this previous study, Foram Index value in the waters near the mainland and the eastern, southern, and southwestern parts of Putri Island ranged from 2.4 to 5.53 which indicates that water conditions are very conducive to quite conducive for coral growth (Figure 5).

*Ammonia* abundance indicates a reverse pattern with that of *Amphistegina.* In locations where *Ammonia* is quite abundant, *Amphistegina* abundance is low. *Ammonia* consists of three species including *Ammonia beccarii, Ammonia convexa,* and *Ammonia* sp. They are widely distributed mainly in the southwest to the northwest part of Putri Island. Those locations composed by finer types of sediment such as sandy mud and sandy silt (characterized by gravel muddy sand). Boltovskoy & Wright (1976) stated that *Ammonia beccarii* is commonly found in sandy mud sediments. A finer composition of sedimentary types will increase the turbidity of the waters and decrease the light penetration. Thus only certain types of foraminifera can survive in these conditions. *Ammonia* is known as a cosmopolitan species that can survive in a wide range of environmental fluctuation, contaminated area, or extreme environments and has a high life tolerance range in obtaining food or nutrition sources (e.g. Alve, 1995; Boltovskoy & Wright, 1976; Sharifi et al., 1991; Yanko-Hombach et al., 2017). A high abundance of *Ammonia* and *Quinqueloculina* may indicate ecologically stressed waters. This is indicated by the high content of organic matter (Barbosa et al., 2009) and the low level of brightness (Natsir, 2010). There was a decrease in the FORAM Index to 1.8-1.98 in the northwestern part of Putri Island which indicates that in this area the environmental conditions are no longer suitable for coral reef growth (Divina et al. 2020).

The strong influence of currents on the abundance of foraminifera can also be observed from the value of the foraminiferal diversity index which is generally between 1-3 (moderate category). Whereas based on the FI value, it is included in the high category or shows a conducive coral reef fertility (Divina et al. 2020, Figure 5). Thus, it can be noted that coral reef communities are not necessarily beneficial for every foraminiferal species, only certain species that are in symbiosis with coral reefs and are able to survive in an aquatic environment with high currents can thrive. In contrast, other species actually decrease in abundance or are even unable to withstand the normally strong current conditions in coral reef habitat areas, thus it can be concluded that the diversity index is not significantly correlated to the FI value.

The lowest diversity index value of 1.85 is found at PN-1433 in the northeast part of the research area. At this station several predominant foraminifera also absent including *Operculina, Discorbinella,* and *Asterorotalia.* Based on the water sample test, this area is considered polluted by oil and fat reaching 8 mg/l, and lead reaching 0.025 mg/l (PPPGL, 2014). This value is above the threshold value of 1 mg/l for oil and fat content and 0.005 mg/l for lead content (Decree of the State Minister of Environment No. 51 of 2004). The high levels of pollutants in the waters can result in decreased environmental stability in this area.

Meanwhile, the evenness index has a low to a high value (0.37-0.78). The low evenness index value (0.37) indicates there are certain species that dominate the foraminiferal community, which is only found at the PN-1409 in the south of Putri Island. At this station, *Amphistegina* was found very abundant (40.56%). A high evenness index is usually inversely proportional to the dominance index. The dominance index of the distribution of foraminifera in all samples of the waters of Putri Island is still relatively low (0.05-0.24). Relatively good environmental conditions lead to a low dominance index and high evenness index because each species can develop evenly in these conditions. Figure 6 shows the spatial distribution of foraminifera indices values in the marine sediment surrounding Putri Island.

## CONCLUSIONS

Benthic foraminifera found in the waters surround Putri Island consists of 62 species belonging to 31 genera. Most of the species found are suborder Rotaliina (74.92%) and several species belonged to suborders Miliolina (16%) and Textulariina (9.08%). In general, only benthic foraminifera found in the study area which characterizes shallow waters. There is a difference between the foraminiferal distribution in the east-southwest part and in the southwest-northwest part which might be due to the influence of sediment type, water depths, water currents, and coral reef habitat factors. The waters of Putri Island have moderate to strong current conditions and are considered to greatly affect the abundance of foraminifera. This is indicated by the high abundance of *Elphidium* (14.11%) and *Quinqueloculina* (11.38%), as well as

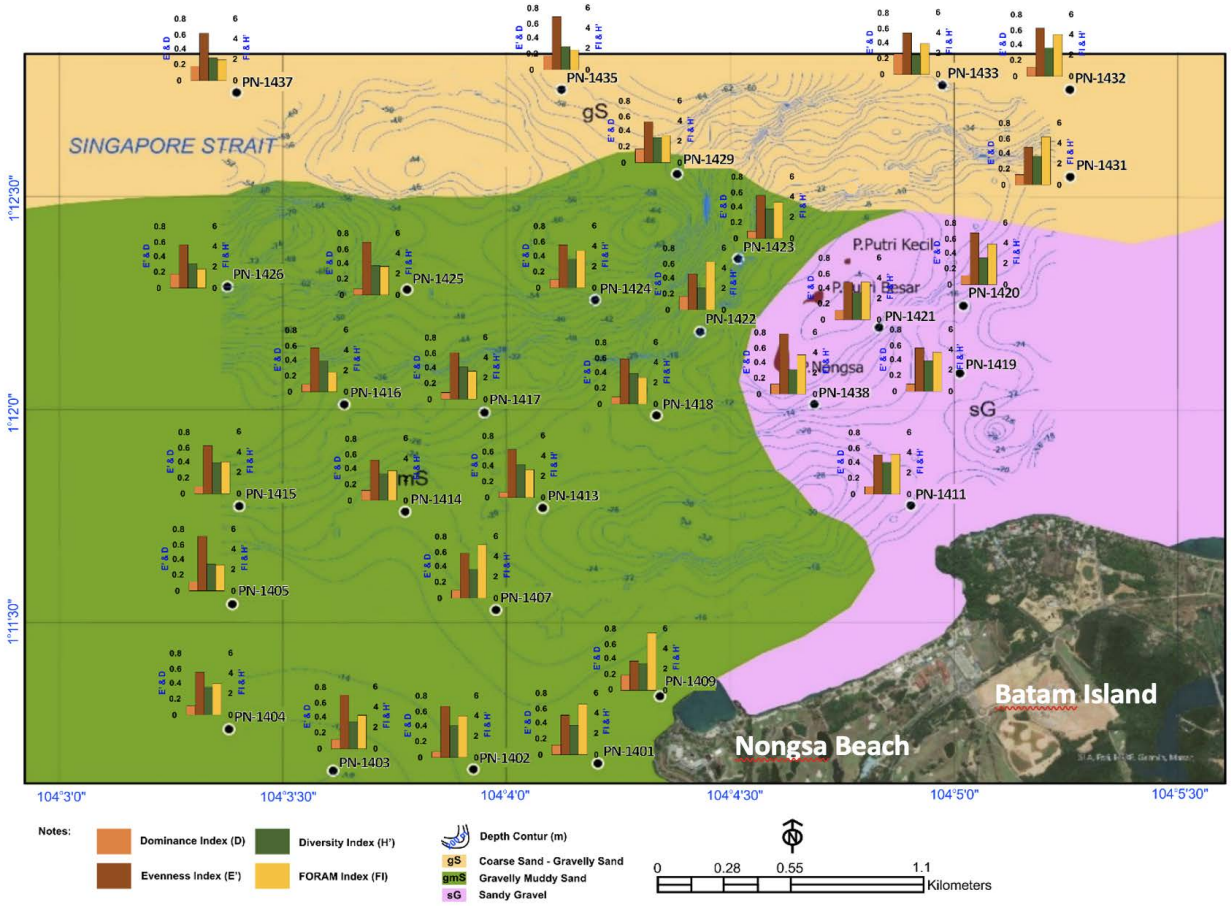


Figure 6. Distribution of foraminifera indices in the marine surrounding Putri Island

indicated by the diversity index value ranging from 1 to 3, belonging to the moderate category.

*Amphistegina* species (14.26%) were found to be very abundant, particularly in the east to the southwest of the research area which is a coral reef habitat. *Amphistegina* abundance demonstrates a reverse pattern with that of *Ammonia*. In locations where the *Amphistegina* species are very abundant, *Ammonia* is found in low abundance and even absent. This is because these two species prefer different types of environmental conditions.

The high levels of pollutants in the northeastern area of the research are also considered to greatly affect the abundance of foraminifera, which is indicated by the lowest diversity index value compared to other locations.

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