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# Correlation of some water quality parameters and Pb in sediment to gastropod diversity in Ambon Island Waters

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***Abstract.*** *The coastal waters of Ambon Island have quite diverse ecosystems that allow for the presence of various organisms, one of which is gastropods. This study aimed to analyze the correlation of water parameters and Pb in sediment with the diversity of gastropods. The research was carried out by observing the density, water quality parameters, and Pb metal in the sediments. Water parameters were measured in situ and analyzed in the laboratory. The distribution of gastropods was analyzed using Principal Component Analysis (PCA). At the same time, correlation analysis was performed using the Pearson correlation approach in SPSS v.16. The results showed that the gastropods with the highest density in the waters of Ambon Island were* Terebralia sulcata, Hebra corticata, *and* Nerita patula. *While the species with the lowest density value were* Nassarius olivaceus, Polinices didyma, Lunella cinerea, Conus eburneus, Cypraea isabella, Vexillum plicarium, *and* Columbella scripta. *The Shannon-Wiener diversity index ranged from 1.253–2.622, and the diversity index ranged from 0.083–0.207. It was included in the low category because of the disturbance of water pollution and Pb metal in the sediments. Meanwhile, the dominance index ranged from 0.098 to 0.511, indicating species dominance at several observation stations. The waters' physical-chemical parameters strongly correlating with gastropod diversity are DO and Pb, with respective correlation values of r = 0.656 and r = –0.785.*

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## INTRODUCTION

The coastal waters of Ambon Island have diverse ecosystems, such as mangroves, seagrass, and coral reef ecosystems. This condition allows the presence of associated organisms owing to the availability of food sources and shelter, one of which is gastropods. The availability of food sources for gastropods in the coastal waters of Ambon Island comes from organic materials discarded by the community. In addition, the mangrove ecosystem in coastal areas also contributes to the provision of food for aquatic biota, including gastropods (Peng et al. 2017). Gastropods are a mollusc phylum with the most diverse types, reaching 40,000–100,000 species (Krupnova et al. 2018). Ponnusamy et al. (2016) and Hilmi et al. (2022) reported that gastropods have different sizes and structural features. Some are herbivores, carnivores, carrion eaters, ciliary feeders, or parasites (Suratissa and Rathnayake 2017). The leading members of gastropods are marine fauna (Bouchet and

Rocroi 2005), and the main fauna in mangrove ecosystems (Setyawati et al. 2019; Cheng et al. 2023). In marine ecosystems, gastropods are found in sandy beaches, rocky beaches, mangrove forests, and muddy areas (Suratissa and Rathnayake 2017; Salimi et al. 2021; Reis et al. 2021).

According to Slama et al. (2022), detritus and algae are the primary food sources for gastropods. Gastropods are listed at the second and third trophic levels in the marine ecosystem food chain (Suratissa and Rathnayake 2017). The gastropods that dominate mangrove ecosystems are Littorinidae (e.g., *Littoraria scabra*), Potamididae (e.g., *Terebralia palustris, Telescopium telescopium*), Muricidae, Onchinidae, Cerithidae, and Ellobidae (Hulopi et al. 2022). In mature mangrove forests, Neritidae and Ellobiidae were dominant, whereas in rehabilitation areas, Assimineidae, Potamididae, and Littorinidae were dominant (Pietersz et al. 2022). In the land zone of mangrove vegetation, the dominant gastropods were Ellobidae, Assimineidae, and Neritidae, whereas in mangrove ecosystems, the seafront was dominated by Potamididae (Reis et al. 2021).

Linares et al. (2022) states that the distribution and diversity of gastropods in an area can be influenced by water quality. Water parameters that play an essential role in the distribution and diversity of gastropods include water physicochemical parameters such as dissolved oxygen (DO), pH, salinity, temperature, nitrate, and nitrite (Syahrial et al. 2019). Studies on gastropods in the Ambon Island and Ambon Bay area have been carried out several times. For example, Tetelepta (2019) examined the gastropod community in Waisisil Beach (Central Maluku Regency), Hulopi et al. (2022) examined the distribution of gastropods in the mangrove ecosystem area of Passo Village, and Pietersz et al. (2022) found the distribution of gastropods based on the type of mangrove in the Waiheru Village area. These two studies only covered a narrow area and have not been able to describe the correlation between water parameters and gastropod diversity in the waters of Ambon Island.

In addition, studies on the content of heavy metal Pb in Ambon Island waters have been carried out previously, including research conducted by Souisa (2017) showing heavy metal Pb in Ambon Bay waters ranging from 0.0086–0.5329 mg/L. Male et al. (2017) and Tuahatu et al. (2022) showed that the heavy metal content of Pb in sediments in Ambon Bay waters ranged from 5.75–20.075 mg/kg and 18.25–35.98 mg/kg, respectively. The coastal area of Ambon Island are a place various human activities. Based on this description, research related to the correlation between some waters quality parameters and Pb content in sediments in Ambon Island waters is essential.

## MATERIAL AND METHODS

### Study Area

This study was conducted in the coastal waters of Ambon Island between August and September 2020. Seven research stations were observed: Passo, Poka, Tawiri, Halong, Suli, Rutong, and Waai (Figure 1). The research location was characterized by sandy and muddy sediments (Table 1). Water samples were analyzed at the Laboratory of the *Balai Teknik Kesehatan Lingkungan* (BTKL) in Ambon. Gastropods were identified at the Basic Biology Laboratory, Pattimiura University, Faculty of Mathematics and Science. The concentration of lead metal (Pb) in the sediments was analyzed at the Laboratory of the *Balai Riset Standardisasi Industri* (BARISTAN).

The water sampling included the physical and chemical parameters of the water. Salinity, temperature, pH, and DO were measured in situ, and turbidity, nitrate, and BOD were measured using a sample bottle with a volume of 600 ml. Water was placed in a dark bottle and kept cold in a cool box at a temperature of approximately 2–4 °C. The samples were then taken to the BTKL, to be tested and analyzed.

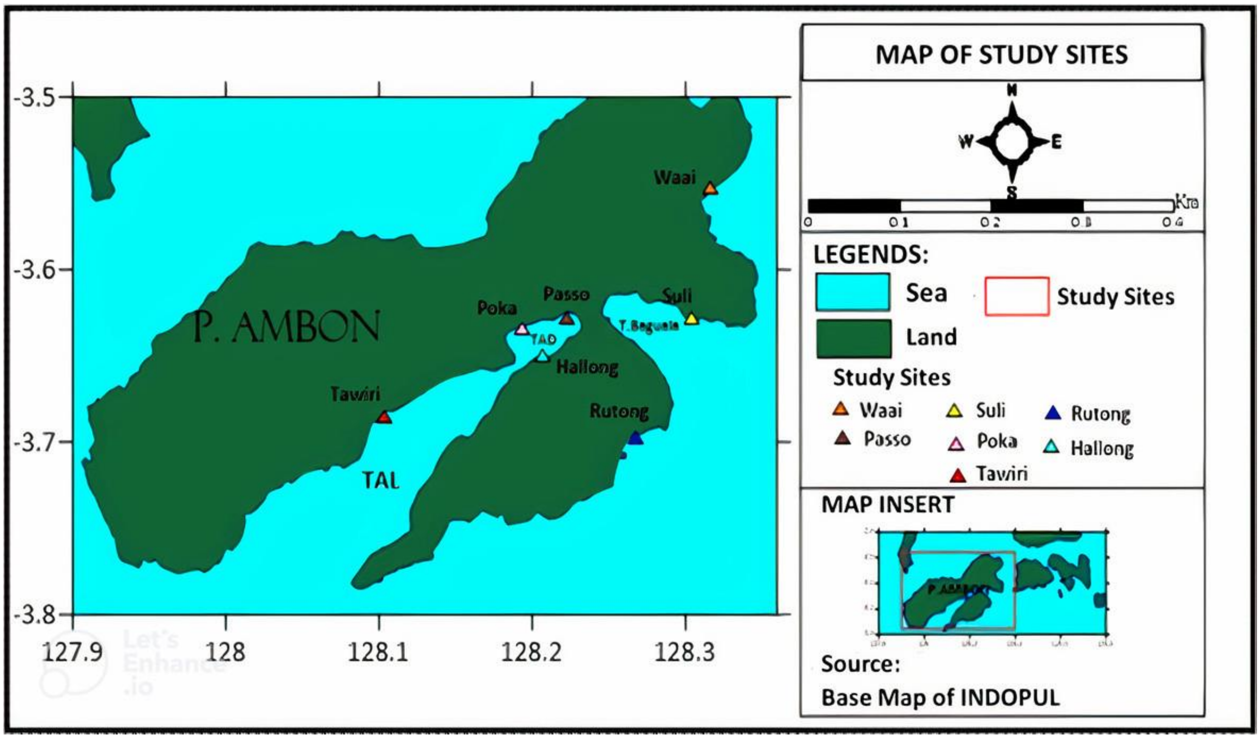


Figure 1 Map of study sites in Ambon Island waters

Table 1 Description of study sites

| Station | Coordinates | Substrates | Site description |
|---|---|---|---|
| I (Passo) | $03^{0}$37’57.4” LS<br>$128^{0}$14’26.5 BT | ▪ Sandy<br>▪ Muddy | There are river mouths and mangrove ecosystems, and they are close to residential areas. |
| II Poka | $03^{0}$38’42.4” LS<br>$128^{0}$11’34.8” BT | ▪ Sandy<br>▪ Muddy | There are river mouths and mangrove ecosystems, and they are close to residential areas, restaurants, and Regional Power Plants |
| III Tawiri | $03^{0}$41’49.4” LS<br>128,$^{0}$6’19.8” BT | ▪ Sandy<br>▪ Muddy | There are river mouths and mangrove ecosystems, and they are close to residential areas, restaurants, and Regional Power Plants |
| IV Halong | $03^{0}$39’33.8” LS<br>$128^{0}$12’33.3” BT | ▪ Sandy<br>▪ Muddy | There are river mouths close to residential areas. |
| V Suli | $03^{0}$37’35.7” LS<br>$128^{0}$18’21.1” BT | ▪ Sandy<br>▪ Dead coral fault | There are river mouths and seagrass ecosystems, and they are close to residential areas. |
| VI Rutong | $03^{0}$42’19.0” LS<br>$128^{0}$16’11.0” BT | ▪ Sandy<br>▪ Muddy<br>▪ Rocky<br>▪ Dead coral fault | There are river mouths and seagrass ecosystems, mangrove ecosystems, and they are close to residential areas. |
| VII Waai | $03^{0}$34’43.4” LS<br>$128^{0}$19’35.7” BT | ▪ Sandy<br>▪ Muddy | There are river mouths and seagrass ecosystems, mangrove ecosystems, and they are close to residential areas. |

### Material

A total of 25 materials were used in this study. Some materials such as thermometers, hand refractometers, pH meters, and DO meters are used in situ to measure water parameters, including temperature, salinity, pH and DO. Several other materials are used in the analysis process in the laboratory, especially for heavy metal content in sediments. Materials in the study can be presented in table 2 below:

Table 2 Material of the study

| No | Materials | Functions |
|---|---|---|
| 1 | GPS | Determine the coordinates of the study sites |
| 2 | Meter | Measure the distance between quadrants and the distance between transects |
| 3 | pH meter | Measuring acidity |
| 4 | Thermometer | Measuring temperature |
| 5 | Refractometer | Measuring salinity |
| 7 | Sample bottle | Filling water samples |
| 8 | DO Meter | Measuring DO |
| 9 | Plastic Samples | Gastropod sample holder |
| 10 | Quadrant | Sampling gastropods |
| 11 | Stationery | Log data |
| 12 | Identification book | Identifying gastropods |
| 13 | Sediment core | Taking sediment samples |
| 14 | Hot plate | Heating the solution |
| 15 | Oven | Drying sediment samples |
| 16 | Analytical balances | Weighing sediment weight |
| 17 | Filter paper | Screening sediment sample arrays |
| 18 | Sieve Shaker | Sieving sediment samples |
| 19 | Aluminium tray | Sieve sediment container |
| 20 | A set of measuring cups | Container measuring and mixing sediment |
| 21 | Mortal | Refining sediment |
| 22 | Gastropod, Sediment, Water | Research samples |
| 23 | Formalin 10% | Sample preservatives |
| 24 | $NHCO_3$ dan HCL | Solvent |
| 25 | Aquades | Diluent |

### Gastropod Sampling

The sampling of gastropods was conducted once at each of the seven observation stations. Quadratic linear transects were used in this study. The transect line was placed perpendicular to the shoreline from the highest to the lowest low tide. At each station, there were six transects with a distance between transects of 20 m, and a distance between quadrants of 10 m, and the quadrant size used was 1 × 1 m. Gastropod samples collected in each quadrant were then placed in a plastic bag and preserved further with formaldehyde at approximately 10% (Kaehler and Pakhomov 2001). Identification was carried out by examining the morphological characteristics of the shell in the form of color, pattern, length, shape, operculum, wrinkles, indentations, and number of turns of the shell.

### Water Sampling

The water sampling included the physical and chemical parameters of the water. Salinity, temperature, pH, and DO were measured in situ, and turbidity, nitrate, and BOD were measured using a sample bottle with a volume of 600 ml. Water was placed in a dark bottle and kept cold in a cool box at a temperature of approximately 2–4 °C. The samples were then taken to the laboratory of the Environmental Health Technology Center, Indonesia (BTKL), to be tested and analyzed.

### Sediment Sampling

Sediment sampling was conducted at seven observation stations. Each sediment sample was taken using a sediment core to a depth of 25 cm and then placed into a plastic bag that had been labelled to accurately analyze the sediment at each location. The samples were then taken to the laboratory for sieving and preparation. The samples were then brought to the laboratory of BARISTAND to analyze the heavy metal plumbum (Pb) for sieving and metal (Pb) content determination.

### Data Analysis

#### *Gastropods Density*

The density of a gastropod is the total number of gastropod individuals found per given unit area. Generally, density is expressed in units of ind/m$^2$ because of its relatively small size and even distribution in a particular habitat such as mangrove sediments. To calculate the density of gastropods, the analytical method used according to Khouw (2009), as follows:

$$\text{Density (ind/m}^2\text{)} = \frac{\text{Number of Individual of a species}}{\text{Area of Sampling Unit}}$$

#### *Shannon Winner Diversity Index (H')*

The diversity index shows the richness of species in a community and the balance in the distribution of the number of individuals per species. The high and low diversity of gastropods found in the aquatic environment is usually an indicator of disturbance to the ecosystem in these waters, so it can be used as an indicator of pollution. The equation used to calculate this index is the Shannon-Wienner equation (Shannon and Wienner 1993):

$$H' = -\sum ni/N \ln ni/N$$

$$H' = -\sum Pi \ln Pi$$

where:
H' = diversity index
ni = the number of individuals species - i
N = the total number of all species
Pi = (ni/N)

Criteria:
$H' < 1$ = Low diversity;
$1 < H' > 3$ = Medium diversity;
$H' > 3$ = High diversity

#### *Evenness Index (E)*

The Gastropod uniformity index or Evenness index is a measure used to measure the level of uniformity or balance in the distribution of gastropod species in an ecosystem. The smaller the organism evenness index value, the more individual distribution of each type is not the same; there is a tendency to be dominated by certain species (Odum 1971). The equation used to calculate this index is:

$$E = \frac{H'}{\ln S}$$

where:
E : Evenness index
H' : Diversity index
S : Number of species

Krebs (1985) states the criteria for the E range as follows:
E < 0.4 : Small population evenness
0.4 < E < 0.6 : Medium population evenness
E > 0.6 : High population evenness

***Dominance Index***

The dominance index measures the extent to which a species influences the community structure and function. A high dominance index indicates a high dominance concentration, meaning that species dominate the community (Odum 1971). To calculate the dominance of certain species in a community, the Simpson dominance index (Odum 1971) was calculated using the following equation:

$$C = \Sigma\ (ni\ /\ N)^2$$

where:
C : Dominance index
Ni : Number of species-i
N : Total of species

Dominance criteria: C close to 0 (C < 0.5) indicates that no species dominates, and C close to 1 (C > 0.5) indicates that there are types that dominate.

**Cluster Analysis**

Cluster analysis (CA) was used to determine the density distribution of gastropods based on habitat characteristics. This analysis was also performed to see the degree of similarity of gastropods at each station. The analysis was performed using the XLSTAT 2014.5.03 software.

**Correlation of Water Quality Parameters and Pb Content to Diversity**

Correlation analysis was carried out to determine the relationship between the physicochemical parameters of the water and the concentration of the heavy metal Pb in sediments with the gastropod diversity index in the waters of Ambon Island. Pearson's correlation analysis was performed using SPSS 16.0 software. The Pearson correlation is a simple correlation that considers the relationship between two variables and is denoted by r. The value of r ranges from –1 to +1; the closer to –1 or +1, the water parameters or Pb metal concentrations show a strong relationship with gastropod diversity. Meanwhile, if the r value is closer to 0, these parameters show a weak correlation.

## RESULT AND DISCUSSION

### Gastropods Density

The number of gastropod species found in the Ambon Island waters was 47, belonging to 17 families and 21 genera (Table 3). The most significant number of gastropods was found in Rutong and Suli, with 22 and 19 species, respectively. In contrast, the gastropods found in Poka and Passo had the lowest number of gastropod species, with 11 and 12 species, respectively. In this study, the number of gastropod species on the Passo coast was lower than that reported by Hulopi et al. (2022), who found 17 types of gastropods. This difference could be due to the broader number of observation points carried out by Hulopi et al. (2022), which included the Baguala Bay area.

Table 3 The density of species and density of gastropods on the coastal waters of Ambon Island

| Family | Genus | Species | Stations | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Passo | Poka | Tawiri | Halong | Rutong | Suli | Waai |
| Neritidae | Nerita | *N. albicila* | | | 0.53 | | 0.10 | | 0.27 |
| | | *N. chamaelon* | 0.30 | | 0.37 | | 0.13 | | |
| | | *N. patula* | | | | | 1.33 | | 0.70 |
| | | *N. polita* | | | 0.33 | | 0.77 | | |
| | | *N. signata* | | | | | 0.07 | | 0.30 |
| | | *N. squamulata* | | | | | | 0.17 | |
| | | *N. undata* | *0.47* | 0.17 | 0.67 | 0.53 | | | |
| | | *N. planospira* | 0.40 | 0.20 | | 0.36 | | | 0.13 |
| Potamididae | Terebralia | *T. palustris* | 0.63 | | 1.27 | | | | |
| | | *T. sulcata* | 1.03 | 0.17 | 11.5 | | 0.50 | | 0.60 |
| Cerithiidae | Clypolmorus | *C. coralium* | 0.33 | 0.37 | | 0.13 | | | 0.50 |
| | | *C. moniliferus* | 0.53 | | | | 1.00 | | 0.67 |
| | | *C. subbrevicula* | | | | 0.20 | | 0.40 | |
| Cypraeidae | Cypraea | *C. annulus* | | | | 0.40 | 0.90 | 0.53 | 0.17 |
| | | *C. moneta* | | | | | | 0.37 | |
| | | *C. palydula* | | | | 0.07 | | | |
| | | *C. isabella* | | | | | 0.03 | | |
| Littorinidae | Litorina | *L. scabra* | 0.70 | 0.43 | 0.77 | | 0.33 | | 0.13 |
| Naticidae | Polinices | *P. didyma* | | 0.07 | | | | | |
| | | *P. sabae* | | | | 0.20 | | | 0.17 |
| Strombidae | Strombus | *S. gibberulus* | | | | 0.30 | | 0.33 | |
| | | *S. labiatus* | | | | 0.17 | | 0.43 | |
| | | *S. luhuanus* | | | | | | 0.30 | |
| | | *S. urceus* | | | | 0.17 | | 0.47 | |
| Columbellidae | Pyrene | *P. ocellata* | | | | | 0.30 | | |
| | Columbela | *C. scripta* | | | | | 0.07 | 0.10 | 0.07 |
| Conidae | Conus | *C. eburneus* | | | | 0.03 | | 0.10 | |
| | | *C. moreleti* | | | | 0.03 | | 0.10 | |
| | | *C. quercinus* | | | 0.03 | | | | |
| Costellariidae | Vexillum | *V. plicarium* | | | | | | 0.03 | |
| Mitridae | Mitra | *M. incompta* | | | | | | 0.07 | |
| Muricidae | Engina | *E. mendicaria* | | | 0.10 | | 0.13 | | |
| | Morula | *M. granulata* | | | | | 0.27 | | |
| | | *M. margariticola* | 0.30 | 0.30 | | 0.20 | 0.30 | 0.17 | |
| | Thais | *T. aculeata* | | | 0.07 | | 0.10 | | |

| **Family** | **Genus** | **Species** | **Stations** | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | **Passo** | **Poka** | **Tawiri** | **Halong** | **Rutong** | **Suli** | **Waai** |
| | | *T. tuberosa* | 0.37 | 0.17 | | | 0.07 | | 0.90 |
| Nassaridae | Hebra | *H. corticata* | | | 0.47 | 8.83 | | 2.00 | 0.33 |
| | Nassarius | *N. bimaculosus* | 0.33 | 0.33 | | | 0.13 | | |
| | | *N. globosus* | | 0.27 | 0.17 | 0.63 | | | 1.07 |
| | | *N. olivaceus* | 0.17 | | | | | 0.37 | 0.20 |
| | | *N. pullus* | | 0.33 | 0.10 | 0.23 | 0.07 | | 0.87 |
| Pisaniidae | Cantharus | *C. fumosus* | | | | | 0.13 | | 0.13 |
| Turbinellidae | Vasum | *V. turbinellus* | | | | | | 0.13 | |
| Turbinidae | Lunella | *L. cinerea* | | | 0.03 | | | | |
| | Monodonta | *M. canalifera* | | | | | 0.03 | | |
| | | *M. labio* | | | | | 0.03 | 0.03 | |
| Trochidae | Trochus | *T. maculatus* | | | | | | 0.03 | |
| 17 | 21 | 47 | 12 | 11 | 14 | 16 | 22 | 19 | 17 |

Table 3 also shows that Passo had the highest density, *Terebralia sulcata*, at 1.03 ind/m$^2$, while the lowest density of *Nassarius olivaceus* was 0.17 ind/m$^2$. The highest density at Poka is *Litorina scabra* (0.43 ind/m$^2$, while the lowest density at *Polinices didyma* was 0.07 ind/m$^2$. The highest density was observed in Tawiri, namely *Terebralia sulcata* (11.50 ind/m$^2$), and the lowest in *Lunella cinerea* (0.03 ind/m$^2$). The highest density was found at Halong, namely *Hebra corticata* (8.83 ind/m$^2$), while the lowest was *Conus eburneus* (0.03 ind/m$^2$). At station V (Rutong), the highest density was *Nerita patula*, 1.33 ind/m$^2$, whereas *Cypraea isabella* had the lowest density at 0.03 ind/m$^2$. At station Suli, the highest density was *Hebra corticata* at 2.00 ind/m$^2$, whereas the lowest was *Vexillum plicarium* at 0.03 ind/m$^2$. At Waai Station, the highest density was *Nassarius globosus*, 1.07 ind/m$^2$, while the lowest was *Columbella scripta* (0.07 ind/m$^2$).

Gastropod density indicates the number of individuals living in a particular habitat, area, or time (Radawan et al. 2020; Salimi et al. 2021). The species with the highest density at each station were *Terebralia sulcata*, *Litorina scabra*, *Hebra corticata*, and *Nassarius globosus*. The different types of gastropods that dominate each station can be caused by differences in habitat characteristics, such as muddy, sandy, and rocky conditions (Syahrial et al. 2019; Supriatna et al. 2023). Schuster and Bates (2023), only certain organisms have a high tolerance for environmental changes due to physicochemical factors, so that these organisms can survive and thrive in these waters. In addition, mangrove ecosystems also play a vital role in the existence of gastropods because they can provide nutrients through mangrove litter production, especially in leaves (Rahman et al. 2020; Wang et al. 2020; Dali 2023).

### Diversity, Evenness, and Dominance Index

The highest value of the diversity index (H) was found at station Rutong at 2.622, followed by Suli at 2.602, Passo at 2.286, Poka at 2.274, and Waai at 2.231. In comparison, the lowest value was found at Tawiri at 1.253 and station Halong at 1.322. The highest diversity index was found at stations Rutong and Suli, while the lowest was at the stations Tawiri and Halong (Table 4).

The high diversity of gastropods at stations Rutong and Suli is due to the large number of species found compared to other stations. Setyawati et al. (2019) state that a community has high species diversity if the community is composed of many species. This is also allegedly due to water quality. According to Slama et al. (2022), good-quality water usually has high species diversity, and vice versa in foul or polluted waters. Hilmi et al. (2022) stated that diversity expresses the variation in species in an ecosystem; when an ecosystem has a high diversity index, the ecosystem tends to be balanced. Conversely, if an ecosystem has a low diversity index, it indicates that it is in a depressed or degraded state.

Table 4 Diversity (H), evenness (E), and dominance (C) index of gastropods in Ambon Island Waters

| **Stations** | **Diversity Index (H)** | **Evenness Index (E)** | **Dominance Index (C)** |
|---|---|---|---|
| Passo | 2.286 | 0.190 | 0.130 |
| Poka | 2.274 | 0.207 | 0.114 |
| Tawiri | 1.253 | 0.090 | 0.504 |
| Halong | 1.322 | 0.083 | 0.511 |
| Rutong | 2.622 | 0.119 | 0.098 |
| Suli | 2.602 | 0.137 | 0.183 |
| Waai | 2.231 | 0.147 | 0.173 |

Meanwhile, the low diversity index found at Stations Tawiri and Halong was because the number of individuals of each species was different, and there was a tendency for one species to dominate. Changes in the quality of aquatic environments can threaten the sustainability of certain types of biotas. Species diversity in an area is influenced by several factors, including contaminated substrates, availability of food sources, inter- and intra-species competition, disturbances, and conditions of the surrounding aquatic environment, so that species with a high tolerance will increase. In contrast, those with low tolerance decrease (Wulansari and Kuntjoro 2018).

The Evenness Index (E) describes the number of species or genera that dominate or vary. The results of the Uniformity Index (E) calculation obtained data at Passo Station 0.190, Poka Station 0.207, Tawiri Station 0.090, Halong Station 0.083, Rutong Station 0.119, Suli Station 0.137, and Waai Station 0.147. The uniformity index (E) ranged from 0 to 1. If the E value is close to one, it describes a condition where all species are abundant (balanced evenness). Meanwhile, if the value of E is close to 0, then the evenness of the species is not balanced. In other words, the evenness index values at the seven observation stations were categorized as having low uniformity in conditions where the evenness of species was unbalanced.

This is in line with the Dominance Index value (C) obtained, namely, the dominance of a species that affects the low diversity of gastropods in Ambon Island waters. The high dominance of a species can be caused by several factors, such as polluted habitat conditions, so that only species that are tolerant to pollution can live in this habitat, or the availability of abundant food sources for certain species so that other species cannot compete.

The highest dominance index value was found at Tawiri station at 0.504 and the Halong station at 0.511. The results are categorized as a type that dominates the other types. At both stations, the dominant species were *Terebralia sulcata* and *Hebra coriticata*. In other words, these two species can adapt well to the surrounding environment around the waters. The locations of the two stations are close to shipping ports, sea transportation, residents, and rivers that flow into the sea. Therefore, it is suspected that the water is unsuitable for organisms, including gastropods. According to Pasztor et al. (2016), only certain organisms have a high tolerance for environmental changes resulting from physicochemical factors, so that these organisms can survive and thrive.

### Spatial Distribution of Gastropods (Cluster Analysis)

Based on the results of the analysis, there were 47 species of gastropods spread over seven observation stations, indicating that information about spatial distribution is centered on axes 1 and 2; the most significant contribution is axis 2, namely 70%. This value is sufficient to explain the variance of the total diversity in studying each variable on the two main axes. This means that several species of gastropods were scattered and found at all observation stations. Figure 2 shows the distribution of clusters of gastropods at each station. Group 1 is represented by the species *Hebra coriticata* (Hbc), *Strombus gibberulus* (Stg), and *Clypolmorus subbrevicula* (Cub), all of which are present at stations of Halong and Suli (group 2) is represented by

*Terebralia sulcata* found at Station of Tawiri and for group 3 namely *Clypolmorus moniliferus* (Cmi), *Cantharus fumosus* (Cnf), and *Nerita polita* (Npa) at Station V (Rutong).

Group 1 is represented by the species *Hebra coriticata* (Hbc) with high-density values found at Halong and Suli Stations, which have the same sandy substrate and are grown in seagrass ecosystems where *Hebra coriticata* lives and are often found in seagrass ecosystems attached to seagrass leaves. *Terebralia sulcata* represents Group 2 with a high density value. Found at Tawiri station, this species lives at the bottom of the substrate and attaches to mangrove roots. In addition, *Terebralia sulcata* can survive under unfavorable water conditions. This could be attributed to the high density of *T. sulcata*. While group 3 is represented by *Nerita polita*, found at the station of Rutong, this species has a high density. This may be due to normal water conditions and is still suitable for gastropod life.

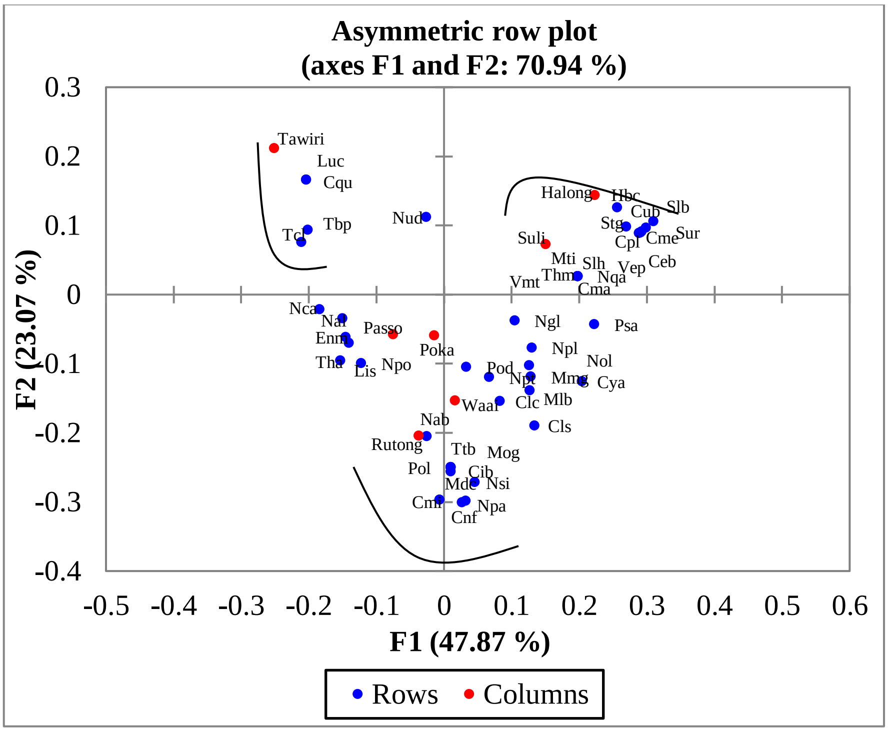


Figure 2 Corresponding factorial analysis graph of gastropod density distribution on axes 1 and 2

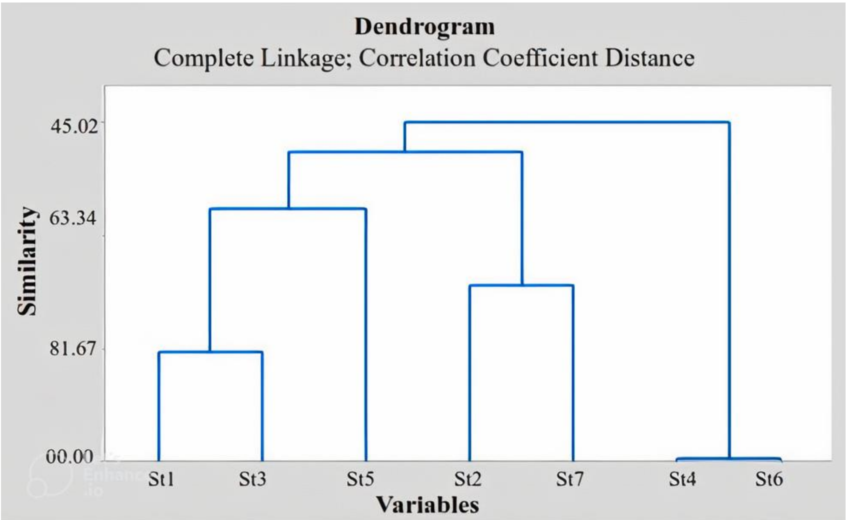


Figure 3 Hierarchical classification dendrogram on axes 1 and 2 from factorial analysis of correspondence between stations and gastropod densities

In addition, the seven-station groupings formed based on Correspondent Factorial Analysis (CA) were confirmed by hierarchical classification. Figure 3 shows a dendrogram of the four groups with the same species at the study station. Group 1 was represented by the Passo and Tawiri stations with the species *Terebralia sulcata*, group 2, station of Rutong with the species *Nerita polita*, group 3, Poka and Waai stations with the species *Litorina scabra*, while group 4 Suli and Halong Stations with the species *Hebra coriticata*.

**Correlation of Water Physico-Chemical Parameters and Concentration of Pb in Sediments with Diversity Index**

The correlation between environmental parameters and gastropod diversity showed a positive and negative correlation. The positive correlations, shown by the (+) value, were turbidity, BOD, and nitrate, while the negative correlations, shown by the (–) value, were temperature, salinity, DO, pH, and Pb in the sediment (Table 5). The temperature correlation with the Diversity Index was –0.308, which means it has a weak correlation level because the correlation values obtained are at intervals (0.21–0.40). In comparison, the direction of the correlation (–) is the opposite, which means that the higher the temperature, the lower the diversity of gastropods. According to Patty and Huwae (2023), rising water temperatures affect the decrease in dissolved oxygen levels in the water. Therefore, it will also affect the existence of aquatic biota, and the level of diversity of aquatic organisms will also decrease.

The turbidity correlation with the diversity index was +0.107, which means there is no correlation because the correlation values are in the interval (0.00–0.20). At the same time, the direction of the correlation (+) is unidirectional, which means that the higher the turbidity, the higher the gastropod diversity index (Siswansyah and Kuntjoro 2023). Odum (1971) reported that gastropods are filter feeders. Gastropods can survive unfavorable water conditions and contaminants that accumulate in their bodies (Marsden and Baharuddin 2015; Krupnova et al. 2018; Menon et al. 2022; Fitria et al. 2023). The BOD correlation with a diversity index of –0.148 means that the correlation is weak because the correlation values obtained are at intervals (0.00–0.20). The direction of the correlation is (–), that is, the correlation is in the opposite direction, which means that the higher the BOD value, the lower the gastropod Diversity Index. There is a negative correlation between high levels of BOD and low diversity of gastropods, because BOD is the oxygen content of water needed to degrade organic matter in water by aerobic microbes biologically. High BOD levels indicate competing organisms (microbes) that use oxygen. As a result, the level of dissolved oxygen in the water for gastropod respiration is decreasing, which can affect the presence of gastropods.

The DO correlation with a diversity index of +0.656 indicates a strong correlation level because the correlation values obtained are in the interval (0.61–0.80). This finding aligns with a report by Ayu et al. (2015), who found a strong correlation (+7.33) between DO concentrations and gastropod diversity in the waters of the Kreo River, Semarang City. The correlation between DO and gastropod diversity is because dissolved oxygen content plays a critical role in the survival of gastropods in the respiration and photosynthesis of aquatic organisms. Linares et al. (2022) stated that aquatic organisms depend on dissolved oxygen to sustain life. According to Bhandari et al. (2021), dissolved oxygen is a limiting factor that, if its availability in water is insufficient, will hamper the activity of aquatic biota. At the same time, Nitrate correlation with a diversity index of +0.402 means it has a moderate level of correlation because the correlation values obtained are at intervals (0.41–0.60). On one hand, the correlation of salinity with a diversity index of –0.342 means it has a deficient level of correlation because the correlation values obtained are in the interval (0.20–0.399). Salinity is correlated with gastropods because it affects the osmotic pressure of water, ultimately affecting aquatic biota (Bhandari et al. 2021). The pH correlation with a diversity index of –0.243 means the correlation is low because the correlation values are in the interval (0.20–0.399). According to Kleinhappel et al. (2019), most aquatic biota are sensitive to changes in pH and prefer a pH of approximately 7–8.5, and most aquatic plants die because they cannot tolerate low pH.

Pb correlation with a diversity index of –0.785 means it has a strong correlation level because the correlation values obtained are in the interval (0.60–0.799). At the same time, the direction of the correlation is (–), which shows a relationship in the opposite direction, meaning that the higher the concentration of Pb, the lower the diversity of gastropods. This could indicate that the concentration of Pb affects the reproductive system, decreasing the diversity of gastropods. This finding is in line with the report of Ansaldo et al. (2009), who found a decrease in gastropod fecundity as a result of Pb contamination ($p < 0.01$). The same indication was reported previously by Amusan et al. (2002), who found that Pb concentrations > 5 mg/l had a significant (0.965; $p < 0.01$) impact on the mortality of terrestrial gastropods. Gastropod mortality has a strong influence on decreasing diversity. Gastropods are benthic animals that live and are active at the bottom of waters, and they do not have direct contact with seawater during low tide. Heavy metals precipitate at the bottom of the substrate and form sediment. According to Male et al. (2017) and Tuahatu et al. (2022), the longer the deposition of lead metal (Pb) in sediments, the higher the amount of Pb in the sediments because lead metal (Pb) has properties that precipitate and forms sediments and cannot decompose.

Over time, lead metal (Pb) will be able to accumulate in the bodies of gastropods that live and forage in the environment. Gastropods have slow movement characteristics, a habitat on the bottom of the water, a detritus diet, and the ability to accumulate chemical compounds in their body tissues. The research results of Wahyudi et al. (2015) on the South Coast of Bangkalan Regency, Madura Island stated that the gastropod species *Cerithidea* sp. live on the bottom of the muddy substrate because there are abundant food particles and *Cerithidea* sp. accumulate lead (Pb) metal with levels that exceed the quality standards set by the government.

Table 5 Correlation of some water parameters and concentration of Pb in Sediments with Diversity Index

| **Parameters** | **r value** | **Correlations** |
|---|---|---|
| Temperature | –0.308 | Low correlation |
| Turbidity | 0.292 | Low correlation |
| BOD | 0.148 | No correlation |
| DO | 0.656 | Strong correlation |
| Nitrate | 0.402 | Medium correlation |
| Salinity | –0.342 | Low correlation |
| pH | –0.243 | Low correlation |
| Pb | –0.785 | Strong correlation |

## CONCLUSION

The gastropods with the highest density in the waters of Ambon Island were *Terebralia sulcata, Hebra corticata*, and *Nerita patula*. While the species with the lowest density value are *Nassarius olivaceus*, *Polinices didyma, Lunella cinerea, Conus eburneus, Cypraea isabella, Vexillum plicarium*, and *Columbella scripta*. DO had a strong positive correlation with gastropod diversity. Meanwhile, Pb has a strong negative correlation with gastropod diversity, which is thought to be related to its effect on the gastropod reproductive system.

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