VOLUME 11 NOMOR 1 JUNE 2024 ISSN 2548 – 611X

JURNAL
BIOTEKNOLOGI & BIOSAINS INDONESIA

Homepage Jurnal: http://ejournal.brin.go.id/JBBI/index

# DIVERSITY AND DENSITY OF MEGABENTHOS IN CORAL REEF ECOSYSTEMS IN KERA ISLAND WATERS, KUPANG DISTRICT, INDONESIA

## Keanekaragaman dan Kepadatan Megabentos pada Ekosistem Terumbu Karang di Perairan Pulau Kera, Kabupaten Kupang, Indonesia

**Alexander L. Kangkan*, Kiik G. Sine and Rini I. Boik**
Faculty of Animal Husbandry Marine and Fishery, University of Nusa Cendana, Kupang, Indonesia
*Email: alexanderkangkan@staf.undana.ac.id

**ABSTRACT**
Kera Island belongs to the small islands of the East Nusa Tenggara with the potential conservation of coral reefs and various associated megabenthos organisms. This research aims to a) determine the diversity and density of megabenthos in coral reef ecosystems in Kera Island Waters, b) investigate the grouping between variables from environmental characteristics of megabenthos in coral reef ecosystems in Kera Island Waters, and c) observe the relationship between the diversity and density of megabenthos with the percentage of coral cover in Kera Island Waters. The research method used was a survey with direct measurements in the field. Megabenthos data was taken using the Benthos Belt Transect technique, while the coral cover was taken using the Underwater Photo Transect technique and analyzed using CPCe 4.1 software. The research data were then analyzed for density and percentage of megabenthos, diversity index value, (H') Shannon, coral cover, organic matter, carbonate content, principal component analysis, and correlation. The study's results regarding the diversity index value of megabenthos in Kera Island Waters ranged from 0.796 to 1.631. The similarity of environmental parameters makes two main components. The first includes current velocity, organic content, dissolved oxygen, and depth; the second are carbonate content, TDS, temperature, and salinity characterize the second main component. The average organic matter was 8.32%, while the carbonate content was 50.09%. The coral reefs and megabenthos density had a robust relationship, with a correlation coefficient of 0.93.

***Keywords**: Coral Reefs, Density, Diversity Index, Kera Island, Megabenthos*

**ABSTRAK**
Pulau Kera termasuk dalam pulau-pulau kecil di Nusa Tenggara Timur yang memiliki potensi konservasi terumbu karang dan berbagai organisme megabenthos yang berasosiasi dengannya. Penelitian ini bertujuan untuk a) mengetahui keanekaragaman dan kepadatan megabenthos pada ekosistem terumbu karang di Perairan Pulau Kera, b) melihat pengelompokan antar variabel dari karakteristik lingkungan megabenthos pada ekosistem terumbu karang di Perairan Pulau Kera, dan c) melihat hubungan antara keanekaragaman dan kepadatan megabenthos dengan persentase tutupan karang di Perairan Pulau Kera. Metode penelitian yang digunakan adalah survei dengan pengukuran langsung di lapangan. Data megabenthos diambil dengan teknik Benthos Belt Transect, sedangkan tutupan karang diambil dengan teknik Underwater Photo Transect, yang selanjutnya dianalisis dengan menggunakan perangkat lunak CPCe 4.1. Data penelitian selanjutnya dianalisis untuk mendapatkan kepadatan dan persentase megabenthos, nilai indeks keanekaragaman, (H') Shannon, tutupan karang, bahan organik,

***Received**: 12 July 2024* ***Accepted**: 09 September 2024* ***Published**: 30 September 2024*

kandungan karbonat, analisis komponen utama, dan korelasi. Hasil penelitian mengenai nilai indeks keanekaragaman megabenthos di Perairan Pulau Kera berkisar antara 0,796 sampai dengan 1,631. Kesamaan parameter lingkungan tersebut menjadikan dua komponen utama yaitu kecepatan arus, kandungan organik, oksigen terlarut, dan kedalaman menjadi ciri komponen pertama; kandungan karbonat, TDS, suhu, dan salinitas menjadi ciri komponen utama kedua. Rata-rata bahan organik sebesar 8,32%, sedangkan kandungan karbonat sebesar 50,09%. Kerapatan terumbu karang dan megabenthos memiliki hubungan yang kuat, dengan koefisien korelasi sebesar 0,93.

**Kata kunci**: Indeks Keanekaragaman, Kepadatan, Megabenthos, Pulau Kera, Terumbu Karang

## INTRODUCTION

Coastal ecosystems consist of various vital habitats to reinforce the marine biodiversity and have many important benefits and ecological and economic functions (Puryono et al. 2019). Coral reefs are one of the unique ecosystems that have these functions (Putri et al. 2023), as a habitat for marine biota, protecting the coast from ocean waves (Riyantini et al. 2023), and a marine tourism attraction (Wijayanto et al. 2021). Kera Island Waters are included in the Marine Natural Tourism Park Area Teluk Kupang (Tanody et al. 2022) and the Sawu Sea Waters National Park (Idris et al. 2023). The conservation area is important in maintaining biodiversity and preserving marine ecosystems in the region. The percentage of coral reef cover in Teluk Kupang ranges from 11.16-46.3% (Foenay et al. 2011) and around the waters of Kera Island is 14% (Kangkan et al. 2022). Coral reefs are important habitats for marine biodiversity (Hughes et al. 2018), including fish, mollusks, and other invertebrates. It is fertile and rich in food, with shape and growth characteristics making the ecosystem a place for many types of marine biota, both flora and fauna. One of the potential resources in coral reef ecosystems is the megabenthos (Tuhumena et al. 2013) because it has high economic value and is a major component in the food chain cycle in coral reef areas. Reducing coral reef ecosystems as megabenthos habitats will broadly impactther related ecosystems and even the interactions of the biota within them (Airoldi et al. 2008).

Megabenthos communities in a coral reef ecosystem have different distributions at various water depths (Miyamoto et al. 2017), and other habitats important in community formation (Stratmann et al. 2022). Slope angle, water clarity, and productivity best explain the distribution of megafauna in coral habitats (Bridge et al. 2011). Megabenthos can be divided into groups with narrow sensitivity, wide sensitivity and groups that fluctuate based on its benefits for humans and the coral reef ecosystem (Arbi and Sihaloho 2017). Several invertebrates in reef habitats have different ways of responding to environmental changes (Mashar et al. 2021).

Marine management requires knowledge of the diversity of benthic organisms that inhabit the waters. Megabenthos diversity, an important indicator for marine monitoring and management, refers to the diversity of species living on the seabed. Measuring megabenthos diversity can provide information about the health of marine ecosystems and the availability of resources for humans (Beaman and Harris 2007). Kera Island is one of a series of small islands in an important conservation area in Indonesia, which protects biodiversity and the marine environment, so it has a high potential for diversity. Various fishing and boat mooring activities are responsible for the decline in fishery resources andhe areas affected by the Seroja cyclone in April 2021 (Avrionesti et al. 2021), causing massive damage to the coral reef ecosystem in the waters. Thus, it is important to directly observe megabenthos to arrange the resources and the management associated with coral reefs. This study will give information about determining the diversity and density of megabenthos in coral reef ecosystems in Kera Island Waters, grouping between variables from environmental characteristics of megabenthos, and investigate the relationship between the diversity and density of megabenthos in Kera Island Watersin, Kupang Regency.

## MATERIAL AND METHODS

### Study area

The choice of location on Kera Island characterized by sand, seagrasses, and coral reef ecosystems, was based on supporting data in the form of documents and reports (Foenay et al. 2011; Directorate of Coastal and Small Islands Empowerment (P4K) 2012). The map below shows the research location in the waters of Kera Island, Kupang Regency, Indonesia. There were four sampling points scattered around the island, marked with black dots on the map with station coordinates (St 1: -10.095 S, 123.550 E; St2: -10.094 S, 123.562 E; St 3: -10.083 S, 123.560 E; St 4: -10.090 S, 123.562 E).

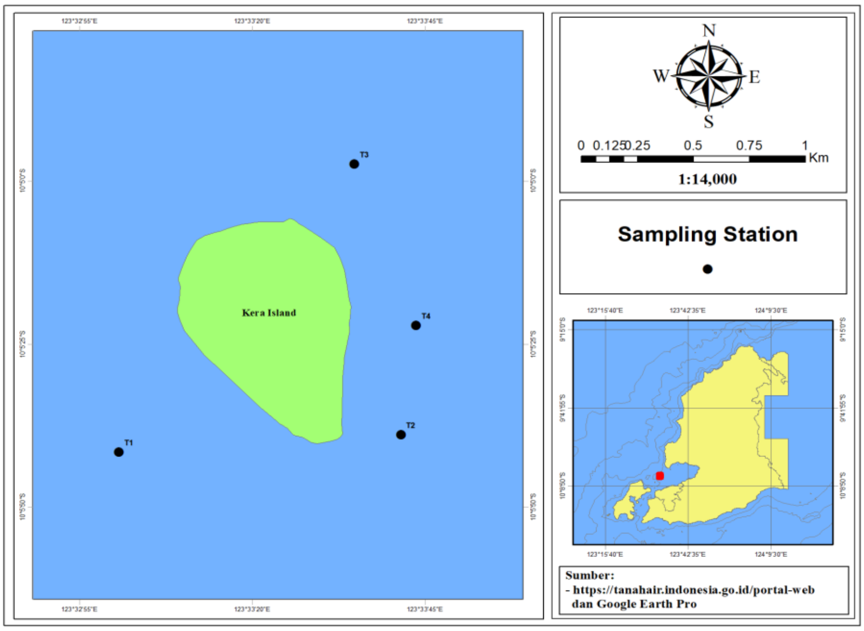


**Figure 1.** Study area of Kera Island water

### Methods

The survey was carried out by observing direct measurements. The data collection was conducted once for each observation station, at a depth of 7-12 meters with an observation transect length of 70 meters with a transect width from the center line to the left and right of 1 meter. So, the observation area were 140 m². Installing observation was divided into several transects on the seabed. Then the number and types of marine life seen in the observation belt was counted. This method allowed researchers to directly observe marine life on the ocean floor and collect data on species diversity and abundance. Megabenthos was observedsing the Benthos Belt Transect method (Arbi et al. 2020).

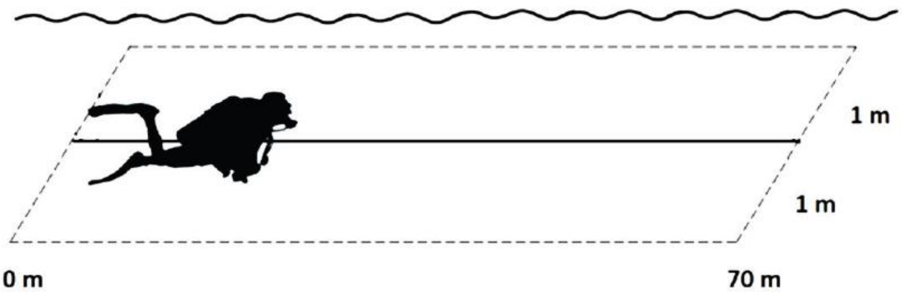


**Figure 2.** Method of taking megabenthos (Arbi et al. 2017).

Coral reef data was collected using the Underwater Photo Transect method (Giyanto et al. 2010). The photos were analyzed using CPCe 4.1 software (Kohler and Gill 2006). The quality of coral cover was assessed based on coral health criteria (Zamani and Madduppa 2011). Figure 3 shows the data collection procedure using the underwater photography method.

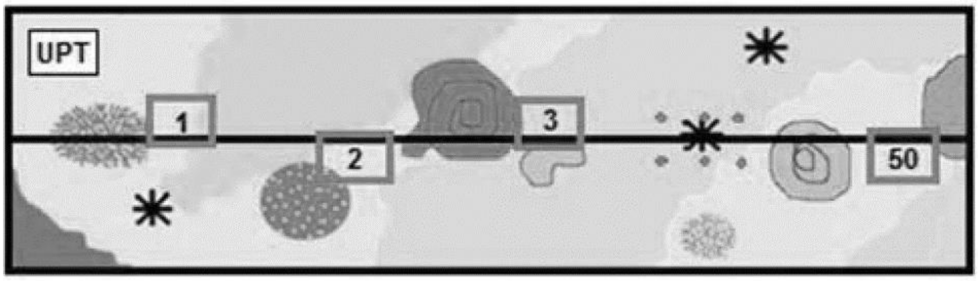


**Figure 3.** Underwater photography method.

**Data analysis**

The abiotic parameter proximity factors for the supporting data of megabenthos diversity, including temperature, salinity, oxygen, depth, current velocity, and pH were carried out by *in situ*. A benthic organism living at the bottom of the waters also needs information on sediment nutrients: sediment organics and carbonate content, which was analyzed using LOI calculation (Heiri et al. 2001; Vereș 2002).

$$\mathrm{LOI}_{550} = ((\mathrm{DW}_{105} - \mathrm{DW}_{550}\ )) * 100 \quad (1)$$

Where LOI550 represents LOI at 550°C (as a percentage), DW105 represents the dry weight of the sample before combustion, and DW550 represents the dry weight of the sample after heating to 550°C (both in g).

$$\mathrm{LOI}_{950} = ((\mathrm{DW}_{550} - \mathrm{DW}_{950}\ )/\ \mathrm{DW550}\ )) * 100 \quad (2)$$

Where LOI950 is the LOI at 950°C (as a percentage), DW550 is the dry weight of the sample after combusting an organic matter at 550°C, DW950 represents the dry weight of the sample after heating to 950°C, and DW105 is again the initial dry weight of the sample before the organic carbon combustion (all in g).

Density analysis and attendance percentage (Arbi et al. 2020).

Density (ind/m$^2$) = $\frac{total\ number\ of\ species\ (i)}{Transect\ Belt\ Area\ (140m^2)}$ (3)

Percentage (%) = $\frac{Number\ Species\ \ (i)}{Total\ number\ of\ species} x\ 100$ (4)

Diversity index (Shannon and Weaver 1964).

Shannon Index (H‘) = $-\sum_{i=1}^{i}(Pi * lnPi)$ (5)

Where: pi, the proportion of individuals of i-th species in a whole community; ln, usually the natural logarithm, but the base of the logarithm is arbitrary (10 and 2 based logarithms are also used); Pi, n/N (n - individuals of a given type/species; and N, the total number of individuals in a community).

The principal component and correlation were analyzed using the open-source Past 4.03 software. The analysis allows for reducing dimensions to be easily read and interpretedith little loss of information (Hammer and Harper 2005). Then, a correlation analysis (Chernick and Friis 2003) was carried out to see the relationship between coral reef health and the density of megabenthos found in Kera Island waters.

## RESULTS AND DISCUSSION

**Density and percentage of megabenthos**

The research results on data in the waters of Kera Island show six megabenthos families with different densities and percentages. The sea urchin megabenthos target species group was the highest and lowest target species in the sea cucumber and lobster target species groups. Figure 4 compares the density of the different megabenthos species that were most dominant and the least found in the research location.

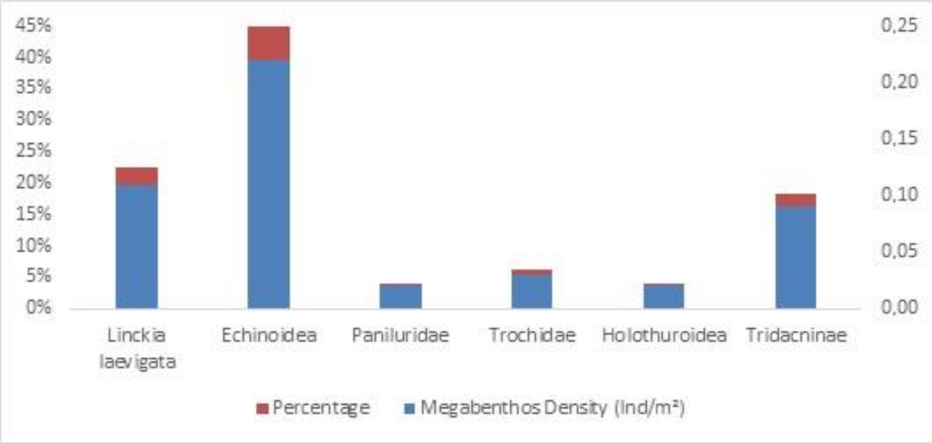


**Figure 4.** Megabenthos density and percentage in Kera Island waters.

In Figure 4, the highest megabenthos density were dominated by Echinoidea species of 0.22 ind/$m^2$ with a percentage of 44.90%, followed by *Linckia laevigata* of 0.11 ind/$m^2$ with a percentage of 22.45%, Tridacninaese of 0.09 ind/$m^2$ with a percentage of 18.37%, Trochidae of 0.03 ind/$m^2$ with a percentage of 4.12%, and finally the types of Holothuroidea and Paniluridae each of 0.02 ind/$m^2$ with a percentage of 4.08%. This difference can be affected by several coral fractures, which are medium for algal growth and serve as a food source for Echinoidea (Nyström et al. 2000). The abundance of sea urchins in the waters of Kera Island can be due to the availability of algae and seagrass, water quality and appropriate substrates, and the protection of the waters. Sea urchins are echinoderm organisms with herbivorous properties (Tavares et al. 2020). They generally consume algae and seagrass on coral reefs, which helps maintain a balance in the growth space of coral reefs by decreasing the number of macroalgae. Sea urchins live in groups on coral reef flats, branching corals, and rubble, which serve as their habitat and protection. Water quality and protection are important factors affecting their spawning, distribution, abundance, environmental adaptation, and foraging (Purwandatama et al. 2014; Suryanti and Ruswahyuni 2014). Moreover, sandy and rocky areas are also good habitats for megabenthos species because they make it easier to find food, move, and protect from predators. Megabenthos also favors the hard coral genera of the Acropora type more than the genera of the Porites type (Moran 1990). Complex coral reef habitats provide alternatives, for example, more gaps and holes in living space or surface area, and adequate shelter to support fauna (Arbi et al. 2020).

**Megabenthos diversity index in Kera Island waters**

The Shannon diversity index can be calculated for each research station based on the research data. The data included Shannon diversity index values for four research stations: St I, St II, St III, and St IV. The Shannon diversity index results shows that species diversity in St II and St IV was higher than in St I and St. III. High species diversity in a research location indicates healthier and more sustainable environmental conditions (Table 1).

**Table 1.** Megabenthos diversity index in Kera Island waters.

| Shannon_H | St I | St II | St III | St IV |
|---|---|---|---|---|
| Value | 0.898 | 1.369 | 0.796 | 1.631 |

St.: Station.

Table 1 shows the difference in diversity index between observation stations. The highest score was at station IV of 1.631, followed by station II at 1.369, station I at

0.898, and finally, station III at 0.796. The diversity index ranged from 0.796–1.631, which was a low value. The value of diversity indicates the stability of the community, whereas a great index value indicates a direct proportion to life in these waters. Diverse communities will show good habitat conditions in these waters; unhealthy reef habitats in Kera Island waters cause low diversity index value. Coral reefs provide food sources, spawning grounds, and nursery grounds to provide diversity for the inhabitants. The condition of this society is characterized by being volatile due to environmental factors. The Shannon diversity index shows the level of species diversity in an environment. The higher the index value, the higher the species diversity in that environment. The Shannon diversity index value at St IV was the highest compared to the other three stations due to the ecological conditions related to ecosystem and environmental quality. At St IV, the percentage of coral cover was relatively higher than that of other stations, and this led to the diversity of megabenthos species. The presence of megabenthos in a healthy coral reef ecosystem is closely related to living habits and eating patterns on the coral substrate. The physical condition of the waters at St IV was also relatively more protected from waves and currents, and tended to have good distribution patterns, reproduction, and feeding grounds. Several factors can also affect species diversity in an environment, such as interactions between species and biological factors. Additionally, more complex and diverse interactions between species at station IV, such as competition and collaboration, are suspected to exist, allowing more species to live and grow together.

### Density and percentage

The density and percentage of megabenthos at observation stations are important parameters in understanding benthic organism communities in marine ecosystems. The existence of megabenthos can vary depending on the waters' geographical location, depth, and environmental conditions. Table 2 presents the density analysis results and the percentage of megabenthos at stations I, II, III, and IV.

**Table 2.** Density (ind/m²) and percentage of megabenthos in Kera Island waters, Kupang Regency.

| No | Family | Station I | | Station II | | Station III | | Station IV | |
|---|---|---|---|---|---|---|---|---|---|
| | | Density (ind/m²) | Percentage | Density (ind/m²) | Percentage | Density (ind/m²) | Percentage | Density (ind/m²) | Percentage |
| 1 | Linckia laevigata | 0.03 | 30.00 | 0.04 | 21.05 | 0.01 | 14.29 | 0.03 | 23.08 |
| 2 | Echinoidea | 0.06 | 60.00 | 0.07 | 36.84 | 0.05 | 71.43 | 0.04 | 30.77 |
| 3 | Paniluridae | - | - | 0.01 | 5.26 | - | - | 0.01 | 7.69 |
| 4 | Trochidae | - | - | 0.01 | 5.26 | 0.01 | 14.29 | 0.01 | 7.69 |
| 5 | Holothuroidea | 0.01 | 10.00 | - | - | | - | 0.01 | 7.69 |
| 6 | Tridacninae | - | - | 0.06 | 31.58 | - | - | 0.03 | 23.08 |
| | Total | 0.10 | 100.00 | 0.19 | 100.00 | 0.07 | 100.00 | 0.13 | 100.00 |
| | Average | 0.03 | 33.33 | 0.04 | 20.00 | 0.02 | 33.33 | 0.02 | 16.67 |
| | ± Sd | 0.03 | 25.17 | 0.03 | 14.60 | 0.02 | 32.99 | 0.01 | 10.22 |

Table 1 shows the highest density of megabenthos was the Echinoidea species at 0.06 ind/m$^2$ with a percentage of 60%, followed by Linckia laevigata at 0.03 ind/m$^2$ with a percentage of 30%, and finally, the Holothuroidea type at 0.1 ind/m$^2$ with a percentage of 10%. The variation and poor density of megabenthos species in the waters of station. I result from a relatively low coral reef average of 2.34, damaging the existence of megabenthos. The waters of Kera Island were also found to have seagrass, which has become a habitat (Riniatsih et al. 2021) of various megabenthos.

Station II showed the highest density of megabenthos was Echinoidea at 0.07 ind/m$^2$ with a percentage of 37%, followed by Tridacninae at 0.06 ind/m$^2$ with a percentage of 32%, Linckia laevigata at 0.04 ind/m$^2$ with a percentage of 21%, and finally, the types of Holothuroidea and Paniluridae each at 0.01 ind/m$^2$ with a percentage of 5%. The variation and density of megabenthos species at station II could be affected by the aquatic substrate (Riniatsih et al. 2021). The bottom texture of the waters and the nutrients in the sediments closely relate to the life of the macrobenthos, in addition to seasonal variations and the characteristics of the bottom substrate (Quijón and Jaramillo 1993). At this station, the percentage of coral cover was 5.54%, which is a bad health condition for the presence of megabenthos.

Station III showed the highest density of megabenthos was Echinoidea at 0.05 ind/m$^2$ with a percentage of 72%, followed by *Linckia laevigata* and Trochidae each at 0.01 ind/m$^2$ with a percentage of 14.29%. The megabenthos density at this station is very small, resulting from the condition of the substrate, namely the coral reef ecosystem. This station has a small percentage of coral cover, namely 0.3%, which is a very bad condition, which is supported by the carbonate content data of 77.78%. One factor that influences the density of megabenthos is the substrate (Riniatsih et al. 2021).

Station IV showed the highest density of megabenthos was Echinoidea at 0.04 ind/m$^2$ with a percentage of 30.77%, followed by Tridacninae and *Linckia laevigata* each at 0.03 ind/m$^2$ with a percentage of 23.08%, and finally, the types of Holothuroidea, Trochidae, and Paniluridae each at 0.01ind/m$^2$, with a percentage of 7.69%. Although the density at this location was low, the number of species was high. In addition, station IV had a coral cover percentage of 11.99%, which is healthier than the other three stations. However, it is still included in the category of unhealthy coral reefs.

The estimation of differences in density and percentage of megabenthos shown by each research station is influenced by living habitats, environmental parameters, beneficial values (Susiana et al. 2018) and the economics of megabenthos in these waters. It is suspected that fishermen widely use the poor megabenthos in Kera Island waters for consumption as a source of protein or some for sale at the local market in Kupang City. In several research stations, the presence of Echinoidea is more dominant than Holothuroidea and Molluska because they are not megabenthos that have economic value in the local or domestic market (Iken et al. 2010). Echinoidea lives in the niches of coral reefs that are good protection from waves and predators (Alvarado 2008). However, in the waters of Kera Island, fishing for marine products puts pressure on the destruction of coral reefs and the loss of economically important fisheries.

**Characteristics of megabenthos environmental parameters in Kera Island waters**

The principal component analysis regarding the characteristics of megabenthos environmental parameters in Kera Island Waters is needed to simplify the interpretation of complex data. The transformation of a collection of correlated variables will be several components that are not linearly dependent. Figure 5 shows the results of the principal component analysis of environmental parameters in Kera Island Waters.

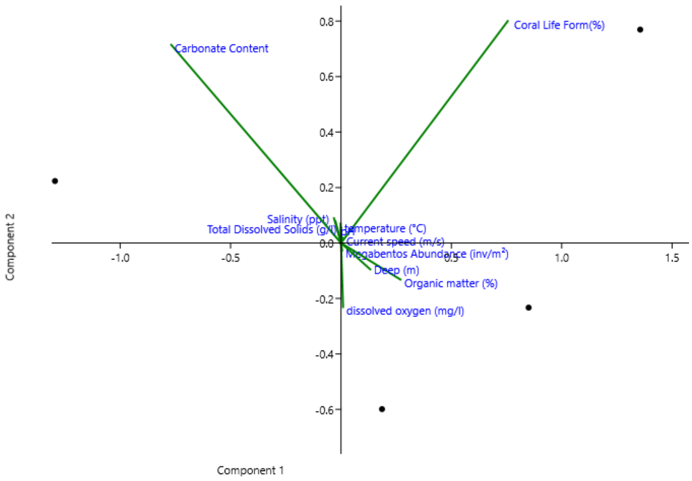


**Figure 5.** Principal components of the environmental parameters of Kera Island waters.

The principal component analysis shows the formation of two main components based on similar environmental parameters. The first component consisted of Station I, II, and IV with similar environmental parameters: dissolved oxygen, organic matter, depth, current speed, megabenthos abundance, and life form. The second component only included station III with similar TDS, carbonate content, temperature, and salinity. The average environmental parameter measurements were current velocity of 0.226 m/s, organic content of 8.32 %, water depth of 6.5 m and temperature of 29.75°C, carbonate content of 50.09 %, Total Dissolved Solids (TDS) of 28.87, and salinity of 30.78 ppt.

The picture above also shows the closeness between environmental parameters based on the angular density between environmental parameters. Megabenthos density is closely related to dissolved oxygen, depth, organic matter, and current velocity, negatively correlating with coral cover. A close relationship is also observed between environmental parameters: TDS, carbonate content, temperature, and salinity. The high carbonate content results from many coral fractures due to destructive fishing and *seroja* cyclones (Yayasan Konservasi Alam Nusantara 2021). The high coral cover results from the protection of these waters. Station IV was located south of Kera, which is relatively protected from waves. Areas facing the open sea with big waves are less able to support the growth of coral reefs (Giyanto et al. 2017).

**Coral cover, organic matter and carbonate content**

The highest percentage of hard coral cover was at Station IV at 11.99%, followed by Station II, I and III at 5.54%, 2.34%, and 0.33%, respectively. Hard corals at all observation stations on Kera Island were in a bad category. The uncontrolled fishing boat activities, such as the anchoring activity of traditional shipping lanes influenced the low health condition of the coral reefs in Kera Island. Other conditions were due to environmentally damaging fishing by fishermen, sedimentation, and anthropogenic (Hadi et al. 2020). High activity of anchor dumping can reduce coral cover, coral size, and density (Flynn and Forrester 2019). If it is associated with carbonate content, it can be seen that station III had a higher value than other stations. This explains several massive corals at the station died. Damage to coral reefs in these waters was exacerbated by the *seroja* cyclone that hit the waters of East Nusa Tenggara in March 2021 (Yayasan Konservasi Alam Nusantara 2021).

Organic matter in aquatic sediments can come from the remains of organisms, such as plankton (Rasheed et al. 2011) and organic detritus, including human waste (Sulardiono et al. 2020). The organic matter content in aquatic sediments can indicate the level of biological productivity and the presence of organic pollutants. Meanwhile, the carbonate content in aquatic sediments can indicate the acidity (pH) level and the availability and stability of nutrients in the waters. High carbonate content may indicate a stable and nutrient-rich aquatic environment supporting biodiversity. However, low carbonate content may indicate unstable environmental conditions, harsh to support life (Figure 6).

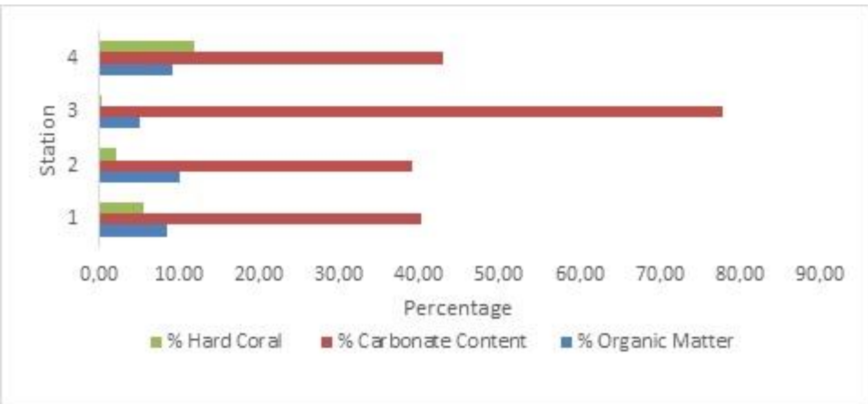


**Figure 6.** Percentage of organic matter, carbonate content, and hard coral.

Based on Figure 6, the average percentage of organic matter content in Kera Island waters varies greatly between research stations in the very low-high category. The average value of the percentage of organic matter content in Kera Island waters sediment ranged from 5.12–10.27%. The lowest sediment organic matter content was found at station III and the highest at station II. The results showed stations I, II, and IV had higher organic matter content than station 3, which had relatively low organic matter content. The overall organic matter in Kera Island waters was in the low category of 3.5–7% to the moderate category of 7–17% (Reynolds 1971). The differences and low values of sediment organic matter content between stations resulted from including organic matter and different sediment types at each research station. The low average organic matter content at station III was influenced by the bottom substrate of this station, which has coral fractures dominated by sand, in which the fraction accumulates less organic matter carried by seawater flows and leaching of the substrate by currents (Yoswaty et al. 2021).

Based on data on carbonate content in Kera Island waters, the value ranged from 39.2–77.78%. Four measurement stations exist with a different carbon content proportion. Station I, II, III, and IV had a carbonate content of 40.36%, 39.23%, 77.78%, and 42.99%, respectively. The difference in carbonate content could be caused by environmental factors and weathering. In general (Andersson 2005), the carbonate content in Kera Island was in the high category (> 35%). Carbonate content in water can affect the health and sustainability of marine ecosystems. Carbonate is important in forming coral reefs and marine sedimentary rocks (Shadrack et al. 2020). Low carbonate content can indicate high acidity of the waters, damaging marine ecosystems and disrupt its biological balance (Putra and Hari Nugroho 2019).

**Correlation of coral cover and megabenthos density in Kera Island waters**

The relationship between the percentage of coral cover and the density of megabenthos showed a strong positive correlation, with a correlation coefficient of 0.93 (Sedgwick 2012). This means that the higher the percentage of coral cover, the higher the density of megabenthos at that location. Conversely, if the percentage of coral cover is low, then the density of megabenthos follows (see Figure 7).

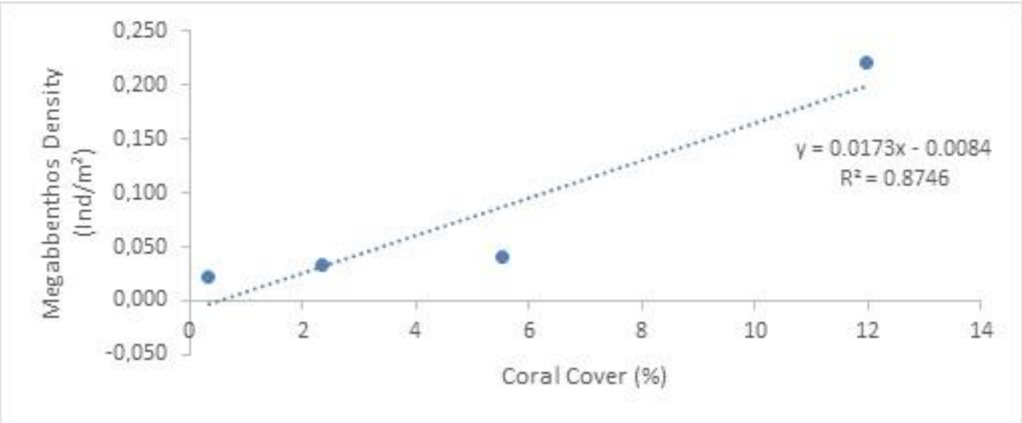


**Figure 7**. Correlation between percentage of coral cover and megabenthos density.

The existence of megabenthos is influenced by the ecology of coral reefs, both biotic and abiotic factors, and the complexity of coral reef ecosystems such as the percentage of coral cover variables. Coral reef ecosystems can support nutrients with unique coral growth patterns, which are ideal substrates and associations of various marine life. As benthic organisms with herbivorous diets, megabenthos make coral reefs a habitat and food source, especially algae. A high percentage of coral cover indicates the health of coral reefs. The healthier the coral reef, the more food sources are available, which will impact the presence of megabenthos.

The close relationship between coral reef cover and megabenthos density results from their mutual relationship; megabenthos habituates in coral reefs. It shows that many species groups are associated with coral reefs (Wulandari et al. 2020). The presence of megabenthos groups indicates that coral reefs are living in that location, and even if the corals have been damaged, the environmental conditions are considered sufficient to support their life. Megabenthos life is also related to organic matter. The results of measurements of organic matter at stations II and IV indicated a higher density of megabenthos than other stations. The megabenthos group on coral reefs is a group of uneconomical species. This results from species with high economic value becoming the target of local fishermen's catches.

## CONCLUSIONS

The diversity index value of megabenthos in Kera Island waters was in the low diversity category, ranging from 0.79–1.63. It indicated that the ecosystem is unstable. Ecosystem stability has implications for the presence of megabenthos and the dominance of certain species groups. Several causal factors include target species capture fisheries and anthropogenic pollution. Thus, good management of the coastal area of Kera Island is needed. Two main components based on similar characteristics of environmental parameters exist: current speed, dissolved oxygen, organic content, water depth, and coral cover characterize the first; carbonate content, total dissolved solid, temperature, and salinity characterize the second main component. The percentage of coral cover and megabenthos density have a strong relationship.

## ACKNOWLEDGEMENT

The researcher thanks Nusa Cendana University for assisting with the regular budget research costs. Acknowledgments were also given to the students and diving club of the Nusa Cendana University, Study program of Aquatic Management.

## REFERENCES

Airoldi L, Balata D, Beck MW (2008) The Gray Zone: Relationships between habitat loss and marine diversity and their applications in conservation. J Exp Mar Biol Ecol 366:8–15. https://doi.org/10.1016/j.jembe.2008.07.034

Alvarado JJ (2008) Seasonal Occurrence and Aggregation Behavior of the Sea Urchin Astropyga pulvinata (Echinodermata: Echinoidea) in Bahía Culebra, Costa Rica. Pac Sci 62:579–592. https://doi.org/10.2984/1534-6188(2008)62[579:SOAABO]2.0.CO;2

Andersson AJ (2005) Coastal ocean and carbonate systems in the high CO2 world of the Anthropocene. Am J Sci 305:875–918. https://doi.org/10.2475/ajs.305.9.875

Arbi U, Sihaloho H (2017) Megabentos monitoring guide, 2nd edn. COREMAP-CTI LIPI, Jakarta

Arbi UY, Harahap A, Cappenberg HAW (2020) Fluktuasi Kondisi Megabentos di Perairan Ternate, Maluku Utara. Jurnal Kelautan Tropis 23:57. https://doi.org/10.14710/jkt.v23i1.5491

Avrionesti, Khadami F, Purnaningtyas DW (2021) Ocean Response to Tropical Cyclone Seroja at East Nusa Tenggara Waters. IOP Conf Ser Earth Environ Sci 925:012045. https://doi.org/10.1088/1755-1315/925/1/012045

Beaman R, Harris P (2007) Geophysical variables as predictors of megabenthos assemblages from the Northern Great Barrier Reef, Australia. In: Todd B, Greene H (eds) Mapping the seafloor for habitat characterization [monograph online]. Geological Association of Canada, St. Johns

Bridge T, Done T, Friedman A, Beaman R, Williams S, Pizarro O, Webster J (2011) Variability in mesophotic coral reef communities along the Great Barrier Reef, Australia. Mar Ecol Prog Ser 428:63–75. https://doi.org/10.3354/meps09046

Chernick M, Friis R (2003) Introductory biostatistics for the health sciences. John Wiley & Sons, New Jersey

Directorate of Coastal and Small Islands Empowerment (P4K) (2012) Kera. Jakarta

Flynn RL, Forrester GE (2019) Boat anchoring contributes substantially to coral reef degradation in the British Virgin Islands. PeerJ 7:e7010. https://doi.org/10.7717/peerj.7010

Foenay RI, Mardani NK, Wiryatno J (2011) Penilaian Efektifitas Pengelolaan Taman Wisata Alam Laut (Twal) Teluk Kupang Nusa Tenggara Timur. Ecotrophic 6:133–138

Giyanto G, Abrar M, Hadi T, Budiyanto A, Hafizt M, Salatalohy A, Iswari M (2017) Status terumbu karang Indonesia 2017 [Status of Indonesian coral reefs 2017]. Jakarta

Giyanto G, Iskandar BH, Soedharma D, Suharsono (2010) Evaluation of the underwater photo transect method for coral reef condition assessment. IPB University

Hadi T, Abrar M, Prayudha B, Johan O, Budiyanto A, Dzumalek A, Alifatri L, Sulha S (2020) Status terumbu karang Indonesia 2019 [Status of Indonesian coral reefs 2019]. Jakarta

Hammer Ø, Harper D (2005) Paleontological Data Analysis. Wiley, Oxford

Heiri O, Lotter AF, Lemcke G (2001) Loss on ignition as a method for estimating organic and carbonate content in sediments: reproducibility and comparability of results. J Paleolimnol 25:101–110. https://doi.org/10.1023/A:1008119611481

Hughes TP, Kerry JT, Baird AH, Connolly SR, Dietzel A, Eakin CM, Heron SF, Hoey AS, Hoogenboom MO, Liu G, McWilliam MJ, Pears RJ, Pratchett MS, Skirving WJ, Stella JS, Torda G (2018) Global warming transforms coral reef assemblages. Nature 556:492–496. https://doi.org/10.1038/s41586-018-0041-2

Idris I, Fakhrurrozi, Johan O, Ninef JSR, Jefri E, Himawan MR (2023) Study of Hard Coral Community Structure and Natural Recruitment on Rote Island in the Sawu Sea Marine National Park (TNP). Jurnal Biologi Tropis 23:434–441. https://doi.org/10.29303/jbt.v23i2.4688

Iken K, Konar B, Benedetti-Cecchi L, Cruz-Motta JJ, Knowlton A, Pohle G, Mead A, Miloslavich P, Wong M, Trott T, Mieszkowska N, Riosmena-Rodriguez R, Airoldi L, Kimani E, Shirayama Y, Fraschetti S, Ortiz-Touzet M, Silva A (2010) Large-Scale Spatial Distribution Patterns of Echinoderms in Nearshore Rocky Habitats. PLoS One 5:e13845. https://doi.org/10.1371/journal.pone.0013845

Kangkan AL, Semedi B, Bintoro G (2022) Coastal area spatial modelling using water ecological parameters, regarding the utilization zone development of Kupang Bay, Indonesia. AACL Bioflux 15:1598–1605

Kohler KE, Gill SM (2006) Coral Point Count with Excel extensions (CPCe): A Visual Basic program for the determination of coral and substrate coverage using random point count methodology. Comput Geosci 32:1259–1269. https://doi.org/10.1016/j.cageo.2005.11.009

Mashar A, Firdaussyia APN, Krisanti M, Hakim AA (2021) Biodiversity of macroinvertebrate in artificial substrate from several habitats at Ponelo Island, Gorontalo. IOP Conf Ser Earth Environ Sci 744:012044. https://doi.org/10.1088/1755-1315/744/1/012044

Miyamoto M, Kiyota M, Hayashibara T, Nonaka M, Imahara Y, Tachikawa H (2017) Megafaunal composition of cold-water corals and other deep-sea benthos in the southern Emperor Seamounts area, North Pacific Ocean. Galaxea, Journal of Coral Reef Studies 19:19–30. https://doi.org/10.3755/galaxea.19.1_19

Moran PJ (1990) Acanthaster planci (L.): biographical data. Coral Reefs 9:95–96. https://doi.org/10.1007/BF00258218

Nyström M, Folke C, Moberg F (2000) Coral reef disturbance and resilience in a human-dominated environment. Trends Ecol Evol 15:413–417. https://doi.org/10.1016/S0169-5347(00)01948-0

Purwandatama RW, Suryanti S, Ain C (2014) Kelimpahan Bulu Babi (Sea Urchin) Pada Karang Massive Dan Branching Di Daerah Rataan Dan Tubir Di Legon Boyo, Pulau Karimunjawa, Taman Nasional Karimunjawa. Management of Aquatic Resources Journal (MAQUARES) 3:17–26

Puryono S, Anggoro S, Suryanti S, Anwar IS (2019) Pengelolaan Pesisir Dan Laut Berbasis Ekosistem. Badan Penerbit Universitas Diponegoro, Semarang

Putra PS, Hari Nugroho S (2019) Distribusi Foraminifera Bentonik Hidup dalam Hubungannya dengan Sedimen Dasar Laut di Selat Sumba, Nusa Tenggara Timur. Jurnal Geologi dan Sumberdaya Mineral 20:17. https://doi.org/10.33332/jgsm.v20i1.382

Putri PID, Sudiarta IK, Prasetijo R, Prasetia IND (2023) Indonesia Coral Reef Garden Sanur Bali: Pemulihan Ekonomi Nasional melalui Restorasi Terumbu Karang. nternational Journal of Community Service Learning 7:168–177

Quijón P, Jaramillo E (1993) Temporal Variability in the Intertidal Macroinfauna in the Queule River Estuary, South-central Chile. Estuar Coast Shelf Sci 37:655–667. https://doi.org/10.1006/ecss.1993.1080

Rasheed M, Al-Najjar T, Damhoureyeh S (2011) Distributions of pigments in reef sediments, contribution of phytoplankton to organic matter budget in coral reef. Nat Sci (Irvine) 03:344–350. https://doi.org/10.4236/ns.2011.35046

Reynolds S (1971) A manual of introductory soil science and simple soil analysis methods. Noumea, New Caledonia

Riniatsih I, Ambariyanto A, Yudiati E (2021) Keterkaitan Megabentos yang Berasosiasi dengan Padang Lamun terhadap Karakteristik Lingkungan di Perairan Jepara. Jurnal Kelautan Tropis 24:237–246. https://doi.org/10.14710/jkt.v24i2.10870

Riyantini I, Harahap SA, Kostaman AN, Aufaadhiyaa PA, Yuniarti MS, Zallesa S, Faizal I (2023) Kelimpahan, Keanekaragaman dan Distribusi Ikan Karang dan Megabentos serta hubungannya dengan kondisi Terumbu Karang dan kualitas Perairan di Gosong Pramuka, Taman Nasional Kepulauan Seribu. Buletin Oseanografi Marina, 12:179–191

Sedgwick P (2012) Pearson's correlation coefficient. BMJ 345:e4483–e4483. https://doi.org/10.1136/bmj.e4483

Shadrack RS, Pohler S, Dutra LXC, Kotra KK (2020) Carbonate sediments from Maui bay (coral coast, Fiji) reflect importance of coral reef conservation. Ocean Coast Manag 198:105381. https://doi.org/10.1016/j.ocecoaman.2020.105381

Shannon C, Weaver W (1964) The theory of mathematical communication. University of Illinois, Chicago

Stratmann T, Simon-Lledó E, Morganti TM, de Kluijver A, Vedenin A, Purser A (2022) Habitat types and megabenthos composition from three sponge-dominated high-Arctic seamounts. Sci Rep 12:20610. https://doi.org/10.1038/s41598-022-25240-z

Sulardiono B, Niniek Widyorini, Suprapto D, Diah Ayuningrum, Arif Rahman (2020) Evaluation of antibacterial activity and molecular characterization of bacteria from Holothuria atra intestine collected from anthropogenic and non-anthropogenic region in Karimunjawa, Indonesia. Biodiversitas 21. https://doi.org/10.13057/biodiv/d210736

Suryanti S, Ruswahyuni R (2014) The Difference in Abundance of Echinoideas on Coral Ecosystem and Seagrass Beds in Pancuran Belakang, Karimunjawa, Jepara. Saintek Perikanan : Indonesian Journal of Fisheries Science and Technology 10:62–67

Susiana S, Niartiningsih A, Amran MuhA, Rochmady R (2018) Suitability Of Location For Restocking Clams Tridacnidae In The Spermonde Archipelago. Jurnal Ilmu dan Teknologi Kelautan Tropis 9:475–490. https://doi.org/10.29244/jitkt.v9i2.19284

Tanody AS, Dewi IAL, Sri N (2022) Ecotourism Development Strategy of Kupang Bay Marine Nature Tourism Park. International Journal of Science and Research (IJSR) 11:203–211

Tavares YAG, Semanovschi N, Camargo JCM, Pellizzari F (2020) Feeding habits of the sea urchin Echinometra lucunter L. (Echinoidea) in a remote Southwestern Atlantic island, Trindade, Brazil. Panam J Aquat Sci 15:303–319

Tuhumena JR, Kusen JD, Paruntu CP (2013) Struktur Komunitas Karang dan Biota Asosiasi pada Kawasan Terumbu Karang di Perairan Desa Minanga Kecamatan Malalayang II dan Desa Mokupa Kecamatan Tombariri. Jurnal Pesisir Dan Laut Tropis 1:6. https://doi.org/10.35800/jplt.1.3.2013.2842

Vereș D (2002) A Comparative Study Between Loss on Ignition and Total Carbon Analysis on Mineralogenic Sediments. Studia Universitatis Babes-Bolyai, Geologia 47:171–182. https://doi.org/10.5038/1937-8602.47.1.13

Wijayanto A, Munasik, Farasara FP, Fadlilah YN, Windiyana AN, Meiliana S, Haryanti D (2021) Coral Reef Coverage and Reef Fish Abundance in Menyawakan Island, Karimunjawa. IOP Conf Ser Earth Environ Sci 750:012057. https://doi.org/10.1088/1755-1315/750/1/012057

Wulandari AT, Sadarun B, Palupi RD (2020) Hubungan Kelimpahan Relatif Karang Hidup Dengan Kepadatan Megabentos Di Perairan Waworaha Sulawesi Tenggara. Jurnal Sapa Laut (Jurnal Ilmu Kelautan) 5:131. https://doi.org/10.33772/jsl.v5i2.12167

Yayasan Konservasi Alam Nusantara (2021) The impact of the seroja cyclone storm on coral reefs in the Sawu Marine National Park. Kupang

Yoswaty D, Amin B, Nursyirwani, Winanda H, Sianturi DD, Lestari A (2021) Analysis of Organic Matter Content in Water and Sediment in The Coastal Waters of Bengkalis Island, Riau Province. IOP Conf Ser Earth Environ Sci 934:012055. https://doi.org/10.1088/1755-1315/934/1/012055

Zamani N, Madduppa H (2011) A Standard Criteria for Assesing the Health of Coral Reefs:Implication for Management and Conservation. Journal of Indonesia Coral Reefs 1:137–146