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UNVEILING MEIOFAUNA DIVERSITY: A STUDY OF COMMUNITY STRUCTURE AND ABUNDANCE IN UNRECLAIMED AND RECLAIMED SHORES, SERANGAN ISLAND, BALI, INDONESIA

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Abstract

Serangan Island is a small island that administratively located in South Denpasar District, Town of Denpasar, and Province of Bali. All of Serangan Island region stated as a village that named Serangan Village which have 4435 peoples. Because Serangan Island is tourist destination, so Serangan Island certainly exposed by tourism development process. As a part of tourism development process is shore reclamation process, an effort to widening Land of Serangan Island which has occured in 1997. That reclamation has enough change environment landscape in Serangan Island. Environment change in shore of Serangan Island, estimate have impact on meiofauna community that life in Serangan shore. Two aspects of meiofauna lives that estimated impacted by reclamation process in Serangan shore are diversity and abundance. To obtain a certainty of reclamation impact to meiofauna live, we have done research about impact of reclamation process to meiofauna live in Serangan Island. In this research, we design this research as a field study. We collect meiofauna samples in two different shores condition, that is shore that impacted reclamation in one side, and shore that no impacted reclamation in the other side. Meiofauna samples collected by core which collected in nine points for each shore condition. Meiofauna extracted by elutriation method, and then meiofauna preservated by 5 % formalin solution. Meiofauna observed and identified by microscope. Then, meiofauna data analyzed by statistical approach by use t-test formula and Shannon Wiener formula for diversity indices. The results of this research are ; 1) meiofauna diversity in shore that impacted by reclamation lower significantly than meiofauna diversity in shore that no impacted by reclamation ; 2) meiofauna abundane in shore that impacted by reclamation lower siginificantly than meiofauna abundance in shore that no impacted by reclamation.

Keywords: Community Structure, Meiofauna, Reclamation, Serangan Island.

INTRODUCTION

Serangan Island is a small administrative region within the South Denpasar District, Denpasar City, Bali Province (Kardana et al., 2023; Nugraha et al., 2020). Officially designated as Serangan Village, the island is home to a population of 4,435 residents. Due to its status as a tourism destination, Serangan Island has been significantly influenced by tourism development initiatives (Arismayanti et al., 2019; Suarta et al., 2018). One notable aspect of this development is the reclamation process initiated in 1997, aimed at expanding the area and enhancing tourism facilities. Before the reclamation efforts, Serangan Island was a compact landmass covering approximately 101 hectares, separated from the main Bali Island. The majority of its shores were characterized by dense mangrove forests, with sandy areas predominantly composed of coral sands. Since the commencement of reclamation in 1997, the land area of Serangan Island has expanded to 365 hectares, leading to substantial changes in

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its landscape and environment, particularly on the southern and western sides. The island is now connected to the mainland of Bali by an asphalt road. While the reclamation has facilitated physical connectivity, it has also taken a toll on the northern and western mangrove forests, leaving them in a damaged state. Despite this, the eastern and southern shores of Serangan Island remain relatively unaffected and are in good condition.

In connection with the altered landscape resulting from the reclamation process on Serangan Island, there is a growing concern about its potential impact on the coastal ecosystem's life systems. One crucial element of this life system that is susceptible to the effects of reclamation is the meiofauna community. Meiofauna, the intricate assembly of small marine zoobenthos inhabiting the sandy and muddy substrates of marine ecosystems (Gallucci et al., 2020; Pan & Pratolongo, 2021; Zeppilli et al., 2017), assumes a pivotal role in upholding ecological equilibrium. As expounded by Schratzberger and Ingel (2018), the significance of meiofauna extends throughout marine ecosystems (Schratzberger & Ingels, 2018; Schratzberger & Somerfield, 2020), with their presence taking on particular prominence in the dynamic landscapes of mangrove ecosystems (Bianchelli et al., 2016; Lee, 2016). These diminutive organisms contribute significantly to the intricate web of life in coastal regions (Grzelak & Kotwicki, 2011; Villegas-Martín & Netto, 2019), participating in nutrient cycling and influencing the overall health of these environments (Brenes-Guillén et al., 2022; Yang et al., 2021).

Building upon this ecological narrative, the remarkable density at which meiofauna taxa colonize the sediments of mangrove forests (Abdullah & Lee, 2017; Carugati et al., 2018; Michelet et al., 2021). This finding underscores the vital role played by meiofauna in shaping the biodiversity and ecological dynamics of mangrove habitats (Ghosh & Mandal, 2019; Song et al., 2022). The close relationship between meiofauna and mangrove ecosystems serves as a compelling testament to their ecological importance, with potential ramifications for broader marine systems (Worsaae et al., 2023; Zeppilli et al., 2015).

Understanding the intricate interplay between meiofauna and their habitat, particularly in the context of mangrove ecosystems, is central to unraveling the broader implications of environmental changes such as reclamation. As we delve into the specific case of Serangan Island in Bali, Indonesia, where reclamation processes have transformed the coastal landscape, an exploration of meiofauna dynamics becomes essential. This study seeks to shed light on the impact of such alterations on meiofauna communities, contributing to the broader discourse on the delicate balance within marine ecosystems and the implications for coastal management strategies.

Two crucial aspects of meiofauna life that may be affected by the reclamation process are the community structure and abundance of meiofauna. This concern is grounded in the theoretical framework suggesting that habitat destruction can lead to a decrease in the diversity and abundance of meiofauna. To substantiate these concerns, it is imperative to conduct field research on Serangan Island.

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The aim of this study is twofold. Firstly, the research seeks to comprehensively address key issues related to the impact of shore reclamation on Serangan Island. These issues include understanding the community structure of meiofauna in both reclaimed and unreclaimed shores, assessing the abundance of meiofauna in impacted and unaffected areas, and examining the environmental conditions in both shoreline types and their influence on meiofauna life. The primary goals of the study are, secondly, to evaluate the overall impact of shore reclamation on the ecosystem stability of Serangan Island. This involves considering the broader ecological implications of the reclamation process on the island's coastal areas. Additionally, the study aims to specifically investigate the impact of shore reclamation on meiofauna life, focusing on aspects of diversity and abundance within these microscopic marine organisms.

The anticipated outcomes of this research serve two main purposes. Firstly, it aims to contribute valuable scientific data and information regarding the meiofauna community structure in Serangan Island. This knowledge is crucial for understanding the ecological dynamics of the island's coastal ecosystems. Secondly, the study aims to provide practical insights that can be used as input data for informed policy-making in the design and planning of shore arrangements by the Denpasar Town government. The research outcomes are expected to assist in the development of sustainable and environmentally conscious practices in the management of Serangan Island's coastal areas.

RESEARCH METHOD

Studi Area

The study was conducted in March 2023, focusing on the coastal areas of Serangan Island, located in Denpasar, Bali. The sampling locations included both Unreclaimed and Reclaimed Shores. Serangan Island, known for its tourism significance, provided a dynamic environment for investigating the impact of shore reclamation on meiofauna.

Samples Collection

Meiofauna samples were meticulously collected using a core sampling approach. The substrate was obtained from both reclamation and unreclaimed shores, utilizing a core sampler consisting of a PVC (Polyvinyl Chloride) pipe with a diameter of 4 cm and a length of 10 cm. Each sampling point on both types of shores involved the extraction of 1130.4 cm^3 of substrate (9 x 125.6 cm^3). This standardized sampling method ensured a representative collection of meiofauna from the distinct environments created by the reclamation process.

Identification

The extracted meiofauna from the substrate were preserved using a 5% formalin solution, ensuring the integrity of the specimens for subsequent analysis. Additionally, the specimens were stained with Rose Bengal solution, facilitating the observation and identification process. Microscopic examination was employed to identify species and quantify their abundance. This meticulous identification process was crucial for understanding the diversity and population density of meiofauna in response to the reclamation activities.

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Figure 1: Map of Research Site in Serangan Island, Denpasar, Bali

The Diversity Index, Species Richness Index, and Equitability Index

The diversity index, species richness index, and equitability index are commonly used measures in ecology to quantify various aspects of biological diversity within a given habitat.

Diversity Index

The diversity index is a comprehensive measure that takes into account both the richness (number of different species) and evenness (relative abundance of each species) of a community. One commonly used diversity index is the Shannon-Wiener Diversity Index, represented by the formula: $H' = -\Sigma (pi \ln (pi))$, where 'pi' is the proportion of individuals of the ith species relative to the total number of individuals.

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Species Richness Index

The species richness index specifically focuses on the number of different species present in a given area. It is a straightforward count of the variety of species within a community. The higher the species richness, the more diverse the community is considered to be. However, species richness alone does not account for the abundance of each species.

Equitability Index

The equitability index, often measured using the Pielou's Evenness Index, assesses the evenness of distribution of individuals among different species in a community. It provides insights into how evenly the abundance is distributed across the various species. The formula for Pielou's Evenness Index is: J' = H' / ln(S), where 'H' is the Shannon-Wiener Diversity Index, 'S' is the species richness, and 'ln' is the natural logarithm.

These indices collectively offer a nuanced understanding of the biodiversity within a community. A high diversity index indicates a community with both a high number of species and a relatively even distribution of individuals among those species. Meanwhile, a high species richness index highlights a community with a greater variety of species, and a high equitability index suggests a more balanced distribution of individuals among those species. The simultaneous consideration of these indices provides a comprehensive perspective on the ecological complexity and health of a given habitat.

Data Analysis

The collected data underwent rigorous analysis to unveil the ecological insights into meiofauna communities in Serangan Island. Statistical approaches, such as the t-test formula and the Shannon Wiener formula for diversity indices, were employed to assess the impact of shore reclamation on meiofauna diversity and abundance. This systematic data analysis aimed to provide a robust scientific foundation for the study's objectives and contribute valuable information for further ecological research and environmental management considerations.

RESULTS AND DISCUSSION

Species Composition of Meiofauna

The investigation into the species composition of meiofauna in the coastal areas of Serangan Island yielded insightful findings. Through meticulous observation and identification under a microscope, a diverse array of meiofaunal species was cataloged, providing a snapshot of the intricate web of microscopic life in the studied shores. The investigation into the species composition of meiofauna at Station A (No Reclaimed Shore) and Station B (Reclaimed Shore) on Serangan Island revealed a diverse array of taxa, each contributing to the intricate coastal ecosystem. The density of each species in a 125.6 cm^3 sample is presented in the table below:

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Table 1: Species Composition of Meiofauna in Serangan Island

Taxa Group	Species Name	Density in 125, 6 cm ^{3}	
		Station A (No Reclamated Shore)	Station B (Reclamated Shore)
Copepoda	*Tisbe* sp	7	2
	Miracia sp	11	4
	Macrosetella sp	5	-
	Microsetella sp	6	1
	Canuella sp	8	-
	Laophonte sp	9	5
	Temora sp	4	5
	Harpacticus sp	2	2
Ostracoda	*Cypridina* sp	3	-
	Macrocypris sp	4	2
	Eucypris sp	2	-
	Conchoecia sp	1	1
Nematoda	*Enoplus* sp	14	2
	Enoploides sp	11	1
	Anticoma sp	8	-
	Leptolaimus sp	6	2
	Halalaimus sp	9	1
	Daptonema sp	5	2
	Comacolaimus sp	3	-
	Thalassolaimus sp	4	-
Polichaeta	*Hesionides* sp	8	3
	Ophryotrocha sp	10	3
	Manayunki sp	7	1
	Diurodrillus sp	5	2
	Protodrillus sp	2	-
Oligochaeta	*Aktedrillus* sp	4	-
	Grania sp	3	1
	Heterodrillus sp	1	1
Gastrotricha	*Xenodasys* sp	3	1
	Planodasys sp	1	-
Tardigrada	*Batillipes* sp	4	1
	Hypsibius sp	2	1
Rotifera	*Aspelia* sp	5	2
	Proales sp	3	1
Gnathostomulida	*Haplognathia* sp	6	2
	Gnathostomula sp	2	-
Sipuncula	*Phascolion* sp	3	1
Molusca	*Falsiden* sp	2	1
∑ Spesies		38	27
∑ Individu		193	51

The species composition analysis revealed a variety of meiofauna taxa thriving in both the unreclaimed and reclaimed shores of Serangan Island. Commonly encountered groups included nematodes, copepods, gastrotrichs, and turbellarians, among others. The presence of these

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diverse taxa underscores the richness and complexity of the meiofaunal community in the studied coastal ecosystems. Interestingly, while some meiofaunal species were found to be common to both the reclaimed and unreclaimed shores, there were notable differences in the composition of certain taxa. The reclamation process appeared to have influenced the distribution and abundance of specific meiofauna species, suggesting a nuanced response of these microscopic organisms to alterations in their habitat. The identification of species composition serves as a crucial baseline for understanding the ecological dynamics and responses of meiofauna to environmental changes, particularly those induced by shore reclamation. Further analyses, such as diversity indices and abundance assessments, will provide a more comprehensive picture of the ecological implications of these observed variations in species composition. This study's findings contribute valuable insights to the broader discourse on the impact of anthropogenic activities on coastal ecosystems. Understanding the intricacies of meiofauna species composition is essential for informed conservation and management strategies, ensuring the sustainability of Serangan Island's coastal biodiversity in the face of ongoing environmental changes.

Diversity, Species Richness, and Equitability Index of Meiofaun

The data presented in Table 2 encapsulates key parameters characterizing the meiofauna communities at Station A (No Reclaimed Shore) and Station B (Reclaimed Shore) on Serangan Island. These parameters provide crucial insights into the ecological dynamics and health of the coastal ecosystems under investigation.

Table 2: Diversity, Species Richness, Equitability and Density of Meiofauna

No	Community Parameter	Station A (No Reclamated Shore)	Station B (Reclamated Shore)
1	Diversity Index (H')	3.4509	3.1336
2	Species Richness Index (R)	7.0342	6.6157
3	Equitability Index (E)	0.9487	0.9508
4	Density (∑individu / cm^3)	1.5366	0.4060

Diversity Index (H')

The diversity index (H') is a measure of the richness and evenness of species in a community. In this study, Station A exhibits a higher diversity index (3.4509) compared to Station B (3.1336), indicating that the unreclaimed shore hosts a more diverse meiofauna community. This implies a greater variety of species and a more balanced distribution of individuals in the natural, undisturbed habitat.

Species Richness Index (R)

The species richness index (R) reflects the number of different species present in a given area. Station A boasts a higher species richness index (7.0342) than Station B (6.6157), emphasizing the greater variety of meiofaunal species in the unreclaimed shore. This underscores the importance of maintaining natural shorelines for sustaining biodiversity.

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Equitability Index (E)

The equitability index (E) assesses the evenness of species distribution within a community. Both stations demonstrate high equitability, with Station A scoring 0.9487 and Station B 0.9508. This suggests a relatively even distribution of individuals among the different meiofauna species, contributing to a balanced ecological community structure in both settings.

Density (∑individuals/cm³)

Measured as the sum of individuals per cubic centimeter, the density parameter provides insights into the abundance of meiofauna. Station A exhibits a higher density (1.5366 individuals/cm³) compared to Station B (0.4060 individuals/cm³). This discrepancy indicates that the unreclaimed shore supports a higher concentration of meiofauna, further highlighting the potential impact of shore reclamation on the abundance of these microscopic organisms. In summary, the data in Table 2 unveils a nuanced picture of meiofauna communities in the context of shore reclamation. While the unreclaimed shore excels in diversity, species richness, and density, both stations demonstrate high equitability. These findings emphasize the intricate relationships between anthropogenic activities, habitat alterations, and the ecological dynamics of meiofauna communities, reinforcing the importance of thoughtful conservation and management strategies in coastal environments.

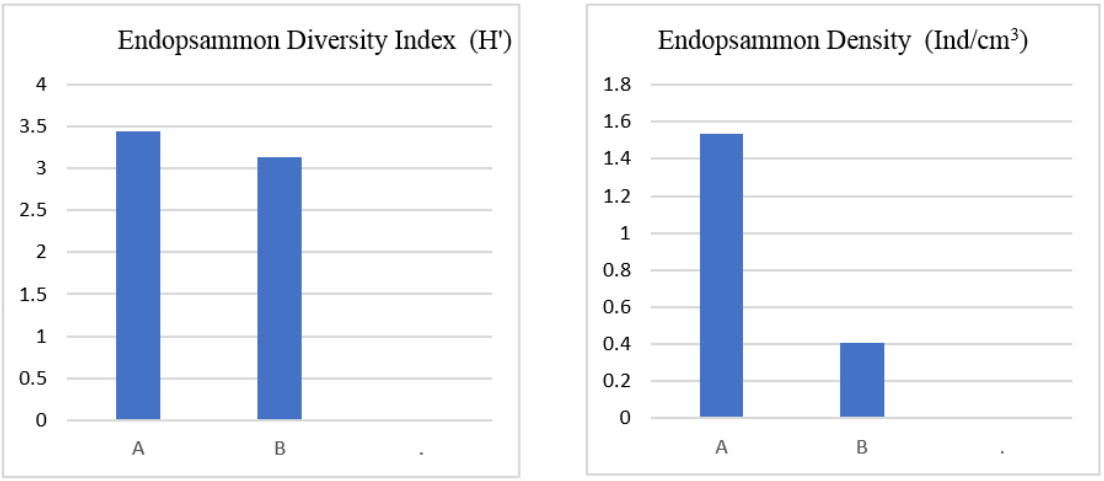

Figure 2: Diagram of Endopsammon Diversity and Endopsammon Density

Differences of Meiofauna Diversity between Stations

Based on analyzed result by student test (t-test), the meiofauna diversity between reclamated shore and no reclamated shore appear different significantly. That is showed by t value = 3,03 in df = 30 and α = 0,05. These results showed that reclamation process can decrease meiofaunadiversity, so that meiofauna diversity in reclamated shore lower than meiofauna diversity in no reclamated shore.

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Environment Parameters Around of Serangan Island

Environment character around of Serangan Island can show by physical and chemical characters as follows:

Tabel 3: Physical and Chemical Characters of Serangan Environment

No	Physical and Chemical Parameter	Station A (No Reclamated Shore)	Station B (Reclamated Shore)
1	Water Temperature (° C)	26,4	27,7
2	Water Salinity (ppt)	30,5	31,0
3	Water pH	9,45	9,39
4	Dissolve Oxygen (DO)	0,09	0,01

DISCUSSION

The meiofauna diversity and abundance in shore that impacted by reclamation process lower than meiofauna diversity and abundance in shore that no impacted by reclamation process. The fact showed that reclamation process has been give destructive effect to meiofauna life. This statement based on some reason that is; 1) reclamation process can hoard and damaging meiofauna habitat, so that meiofauna can lost their habitat and all of their life supporting system, like mangrove vegetation, soft substrate, and favorable sea water condition; 2) reclamation process have been killed many meiofauna, so that can decrease meiofauna diversity and abundance. Reclamation that occurred in Serangan Island many years ago caused mangrove deforestation significantly. Based on research finding by Carugati, *et al* (2018) at Italy, mangrove deforestation can remove meiofauna protection system, so that can decrease meiofauna abundance significantly. Carugati, et al (2018) find that meifauna abundance in degraded mangrove around 60, 13 % of meiofauna in intact mangrove. Aligned with this research finding, research by Mutua, *et al* (2013) at Gazi Bay, Kenya finds that mangrove deforestation can decreased diversity and abundance of meiofauna, and need at least 10 years to recovery.

According to Sahoo, *et al* (2013), root system of mangrove has importance role as habitat and protection ground for meiofauna. Sahoo, et al (2013) state that around 43 % of meiofauna population inhabit in root system of mangrove. According to Zeppillii *et al* (2015), shore environmental that changing by human activities (include deforestation) have negative impact to meiofauna life. Reclamation that occurs in Serangan island have been changed Serangan beach landscape because after reclamation many tourism facilities like hotel, restaurant, café, and public occupancy build near the beach. Research finding at Losari Beach, Makasar by Yusal, et *al* (2019) concluded that pollutant from hotel, restaurant, and cafe can decrease the meiofauna diversity and abundance. Renan da Silva *et al* (2022) state that coastal area with high densities of peoples tend produced high pollutant PAHs (Polyciclic Aromatic Hydrocarbons) so that this condition tends to give negative impact to meiofauna that live in coastal habitat. Aligned with this research finding, research by Michelet, *et al* (2021) in French Guinea find that existence PAHs (Polyciclic Aromatic Hydrocarbons), pesticides and PCB (Poly Chlorinated Biphenyl) in mangrove ecosystem can decrease diversity and abundance of

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meiofauna. Whereas, when mangrove ecosystem in good condition, this ecosystem can support meiofauna life very well. Mangrove ecosystem can give comfortable habitat for meiofauna communities, because litter of mangrove leaf can used by meiofauna as food resources, whereas mangrove shading can give cool environment for meiofauna (Zeppillii *et al*, 2018).

According to research finding by Mirera (2007) at Ungwana Bay, Kenya, coastal without mangrove vegetation have lower abundance of meiofauna than coastal with intack mangrove. Related with soft substrate role, soft substrate very important needed as meiofauna habitat, because soft substrate can make meiofauna easier in digging and infiltrate in to substrate deep layer. According to research finding by Mirera (2007), at Ungwana Bay, Kenya, coastal with soft substrates have higher abundance of meiofauna than coastal with arder substrates. Favorable sea water condition has been made meiofauna live in optimal condition. Whereas, shore that no impacted by reclamation process have all of life supporting system that needed by meiofauna, like mangrove shading, soft substrate, and favorable sea water condition.

CONCLUSION

Based on all of research results above, some conclusion that can make is;

1) There are significant differences of meiofauna diversity and abundance between reclamated shore and no reclamated shore;
2) Meiofauna diversity and meiofauna abundance in reclamated shore lower than meiofauna diversity and meiofauna abundance in no reclamated shore ;
3) Reclamation process can hoarding and damaging meiofauna habitat, and also can kill many meiofauna, so that reclamation process can decrease meiofauna diversity and abundance.

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References

1) Abdullah, M. M., & Lee, J. (2017). Structure of mangrove meiofaunal assemblages associated with local sediment conditions in subtropical eastern australia. *Estuarine Coastal and Shelf Science*, *198*, 438–449. https://doi.org/10.1016/j.ecss.2016.10.039
2) Arismayanti, N. K., Sendra, I. M., Suwena, I. K., Budiarsa, M., Bakta, I. M., & Pitana, I. G. (2019). Tourism villages' development in Bali, Mass or alternative tourism? *Journal of Tourism and Hospitality Management*, *7*(2). https://doi.org/10.15640/jthm.v7n2a11
3) Bengen, D.G, 2000, Teknik Pengambilan Contoh dan Analisis Data Biofisik Sumberdaya Pesisir, PKSPL, Fakultas Perikanan dan Ilmu Kelautan, IPB, Bogor

The Seybold Report
ISSN 1533-9211
DOI: 10.5281/zenodo.10319866

4) Bianchelli, S., Buschi, E., Danovaro, R., & Pusceddu, A. (2016). Biodiversity loss and turnover in alternative states in the Mediterranean Sea: a case study on meiofauna. *Scientific Reports*, *6*(1). https://doi.org/10.1038/srep34544

5) Biliana cicin, W. Knecht, 1998, Integrated Coastal and Ocean Mangement, Island Press, Washington.

6) Brafield, A.E., 1983., Lifes in Sandy Shores, Edward Arnold Publisher, London.

7) Brenes-Guillén, L., Vidaurre-Barahona, D., Avilés-Vargas, L., Castro-Gutiérrez, V., Gómez-Ramírez, E., González-Sánchez, K., Mora-López, M., Umaña-Villalobos, G., Uribe-Lorío, L., & Hassard, F. (2022). First insights into the prokaryotic community structure of Lake Cote, Costa Rica: Influence on nutrient cycling. *Frontiers in Microbiology*, *13*. https://doi.org/10.3389/fmicb.2022.941897

8) Carugati, L. Beatrice Gatto, and Eugenio Rastelli, 2018, Impact of Mangrove Forest Degradation on Biodiversity and Ecosystem Functioning, Journal of Scientific Report, Vol: 8 (13298), page: 1 – 11.

9) Carugati, L., Gatto, B., Rastelli, E., Lo Martire, M., Coral, C., Greco, S., & Danovaro, R. (2018). Impact of mangrove forests degradation on biodiversity and ecosystem functioning. *Scientific Reports*, *8*(1). https://doi.org/10.1038/s41598-018-31683-0

10) Day, J.R., C.A.S Hall, Michael Kemp, Arancibia, 1989, Estuarine Ecology, John Wiley and Sons Inc, New York.

11) Gallucci, F., Christofoletti, R. A., Fonseca, G., & Dias, G. M. (2020). The effects of habitat heterogeneity at distinct spatial scales on Hard-Bottom-Associated communities. *Diversity*, *12*(1), 39. https://doi.org/10.3390/d12010039

12) Ghosh, M., & Mandal, S. (2019). Does vertical distribution of meiobenthic community structure differ among various mangrove habitats of Sundarban Estuarine System? *Regional Studies in Marine Science*, *31*, 100778. https://doi.org/10.1016/j.rsma.2019.100778

13) Giere, O., 1993, Meiobenthology, the Microscopic Fauna in Aquatic Sedimen, Springer Verlag, Berlin

14) Gosh, M., and Mandal, S., 2019, Does vertical Distribution of Meiobenthic Community Structure Differ Among Various Mangrove Habitat of Sundarban Estuarine Ecosystem, Regional Studies in Marine Science, https ://doi.org/10.1016/jrsma.2019.100778

15) Gosner, K.L, 1971 Guide to Identification of Marine and Estuarine In vertebrates, A Wiley Interscience Publications, New Jersey.

16) Grzelak, K., & Kotwicki, L. (2011). Meiofaunal distribution in Hornsund fjord, Spitsbergen. *Polar Biology*, *35*(2), 269–280. https://doi.org/10.1007/s00300-011-1071-5

17) Higgins, R.P, dan Thiel, H., 1988, Introduction to the Study of Meiofauna, Smithsonian Institution Press, Washington.

18) Hutching and Saenger, 1987, Ecology of Mangrove, University of Queensland Press, Queensland, Australia.

19) Kardana, I. M., Kristianto, Y., & Widyatmaja, I. G. N. (2023). Model of local community participation in the management of the Ngurah Rai Mangrove Forest area as a tourist attraction in Denpasar City, Bali. *International Journal of Humanities Education and Social Sciences*, *3*(2). https://doi.org/10.55227/ijhess.v3i2.602

20) Lee, S. (2016). Ecological Studies of the Mangrove-Associated meiofauna in southeast Queensland, Australia. *hdl.handle.net*. https://doi.org/10.25904/1912/2617

21) Ludwig and Reynold, 1988, Statistical Ecology, John Wiley and Sons, Inc, New York.

22) Mann, K.H., 1982, Ecology of Coastal Waters, Blackwell Scientific Publication, London. McLusky, D.S., 1989, The Estuarine Ecosystem, Blackie Academic and Professional, London.

The Seybold Report
ISSN 1533-9211
DOI: 10.5281/zenodo.10319866

23) Masithah, E. D., & Islamy, R. A. (2023). Checklist of freshwater periphytic diatoms in the midstream of Brantas River, East Java, Indonesia. *Biodiversitas*, *24*(6). https://doi.org/10.13057/biodiv/d240621

24) McLusky, D.S., 1989, The Estuarine Ecosystem, Blackie Academic and Professional, London.

25) Michelet, C., Zeppilli, D., and Cedric, H., 2021, First Assesment of Benthic Meiofauna Sensitivity to Low Human Impact to Mangrove in French Guinea, Journal of Forest, Vol: 12, No: 3 (338),

26) Michelet, C., Zeppilli, D., Hubas, C., Baldrighi, E., Cuny, P., Dirberg, G., Militon, C., Walcker, R., Lamy, D., Jézéquel, R., Receveur, J., Gilbert, F., Houssainy, A. E., Dufour, A., Heimbürger-Boavida, L., Bihannic, I., Sylvi, L., Vivier, B., & Michaud, E. (2021). First assessment of the benthic meiofauna sensitivity to Low Human-Impacted mangroves in French Guiana. *Forests*, *12*(3), 338. https://doi.org/10.3390/f12030338

27) Mirera, H.O.D., 2007, The Effect of Mangrove Degradation on Fish Abundance and Diversity in Ungwana Bay, Kenya, Tesis of Egerton University, Kenya.

28) Mutua, A.K., Muthumbi, A., Ntiba, M, J., Vanreusel, A, 2013, Pattern of Meiofauna Colonization as an Indicator of Reforested Rhizophora mucronate Mangrove Recovery in Gazi Bay, Kenya, Journal of Marine Science, Vol: 12, No: 1, page: 25 – 35.

29) Netto, S.A., and Galluci, F., 2013, Meiofauna and Macrofauna Communities in Mangrove from Island of Santa Catarina, South Brazile, Journal of Hidrobiologia, No : 53, page 159 – 170.

30) Nugraha, I. G. P., Antara, M., Budiarsa, M., & Paturusi, S. A. (2020). Sustainable tourism in Serangan Village Bali, Indonesia. *Journal of Tourism and Hospitality Management*, *8*(2). https://doi.org/10.15640/jthm.v8n2a7

31) Nybakken, 1988, Biologi Laut, Suatu Pendekatan Ekologis, PT Gramedia, Jakarta

32) Odum, E.P., 1983, Basic Ecology, Sauders College Publishing, Philadelphia.

33) Pan, J., & Pratolongo, D. (2021). Soft-bottom marine benthos. In *CRC Press eBooks* (pp. 180–210). https://doi.org/10.1201/9780429399244-10

34) Renan da Silva, Giovanni, and Analuiza, 2022, Effect of PAHs on Meiofauna from Three Estuaries with Difference Level of Urbanization in South Atlantic, Journal Peer, Vol. 10. e.14407, doi. 10. 7717.

35) Saho, G.., Suchiang, S.R., Anzari, Z.A., 2013, Meiofauna and Mangrove Interaction, A Pilot Study from Tropical Mangrove Habitat, Journal of Marine Biology, Volume: 54, No: 3, page: 349 – 358.

36) Schratzberger, M., & Ingels, J. (2018). Meiofauna matters: The roles of meiofauna in benthic ecosystems. *Journal of Experimental Marine Biology and Ecology*, *502*, 12–25. https://doi.org/10.1016/j.jembe.2017.01.007

37) Schratzberger, M., & Somerfield, P. J. (2020). Effects of widespread human disturbances in the marine environment suggest a new agenda for meiofauna research is needed. *Science of the Total Environment*, *728*, 138435. https://doi.org/10.1016/j.scitotenv.2020.138435

38) Schratzberger, M., and Ingel, J., 2018, The Role of Meiofauna in Benthic Ecosystem, Journal of Experimental Marine Biology and Ecology, Vol. 502, page : 12 – 25.

39) Song, Y., Yan, C., GAO, C., Xu, H., Hua, E., & Liu, X. (2022). Seasonal distribution of meiofaunal assemblages in the mangrove tidal flat of Futian, Shenzhen, China. *Journal of Ocean University of China*, *21*(4), 955–964. https://doi.org/10.1007/s11802-022-4869-6

40) Suarta, I. K., Budiarta, I. P., & Swabawa, A. a. P. (2018). Strategy of developing marine tourism based on Tri Hita Karana in the village of Serangan, Denpasar. *Proceedings of the 1st International Conference on Social Sciences (ICSS 2018)*. https://doi.org/10.2991/icss-18.2018.119

The Seybold Report
ISSN 1533-9211
DOI: 10.5281/zenodo.10319866

41) Underwood, A.J., and Chapman, 1995, Coastal Marine Ecology of Temperate Australia, University of South Wales Press, Sidney, Australia.

42) Viles and Spencer, 1995, Coastal Problem, Geomorphology, Ecology, and Society of the Coast, Oxford University Press, New York

43) Villegas-Martín, J., & Netto, R. G. (2019). Permian macroburrows as microhabitats for meiofauna organisms: an ancient behaviour common in extant organisms. *Lethaia*, *52*(1), 31–43. https://doi.org/10.1111/let.12288

44) Worsaae, K., Vinther, J., & Sørensen, M. V. (2023). Evolution of Bilateria from a Meiofauna Perspective—Miniaturization in the Focus. In *Springer eBooks* (pp. 1–31). https://doi.org/10.1007/978-3-031-21622-0_1

45) Yang, N., Zhang, C., Wang, L., Li, Y., Zhang, W., Niu, L., Zhang, H., & Wang, L. (2021). Nitrogen cycling processes and the role of multi-trophic microbiota in dam-induced river-reservoir systems. *Water Research*, *206*, 117730. https://doi.org/10.1016/j.watres.2021.117730

46) Yusal, M.S., Marfai, Suwarno, and Nurul, 2019, The Ecological Analysis of Meiofauna as a Water Quality Bioindicator in the Coast of Losari Beach, Makassa, Indonesian Journal of Marine Science, Vol, 24, No. 2, page : 81 – 90.

47) Zeppilli, D., Leduc, D., Fontanier, C., Fontaneto, D., Fuchs, S. C. P. C., Gooday, A. J., Goineau, A., Ingels, J., Ivanenko, V. N., Kristensen, R. M., Neves, R. C., Sánchez, N., Sandulli, R., Sarrazin, J., Sørensen, M. V., Tasiemski, A., Vanreusel, A., Autret, M., Bourdonnay, L., . . . Fernandes, D. (2017). Characteristics of meiofauna in extreme marine ecosystems: a review. *Marine Biodiversity*, *48*(1), 35–71. https://doi.org/10.1007/s12526-017-0815-z

48) Zeppilli, D., Sarrazin, J., Leduc, D., Arbizu, P. M., Fontaneto, D., Fontanier, C., Gooday, A. J., Kristensen, R. M., Ivanenko, V. N., Sørensen, M. V., Vanreusel, A., Thébault, J., Mea, M., Allio, N., Andro, T., Arvigo, A. L., Castrec, J., Danielo, M., Foulon, V., . . . Fernandes, D. (2015). Is the meiofauna a good indicator for climate change and anthropogenic impacts? *Marine Biodiversity*, *45*(3), 505–535. https://doi.org/10.1007/s12526-015-0359-z

49) Zeppillii, D., Jozee, and Daniel Leduc, 2015, Is the Meiofauna a Good Indicator for Climate Change and Anthropogenic impact, Journal of Marine Biodiversity, Vol. 45, page : 505 – 535.

50) Zeppillii, D., Leduc, D., and Christoper, F., 2018, Charactyeristic of Meiofauna in Extreme Marine Ecosystem, Journal of Marine Biodiversity, Vol. 48, page : 35 – 71.