**BIODIVERSITAS**
Volume 25, Number 5, May 2024
Pages: 1946-1954

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d250511

# Exploring meiofaunal assemblages in Pujada Bay, Philippines: A glimpse into one of the world's most beautiful bays

**CIRILO O. YBAÑEZ JR.**
Faculty of Agriculture and Life Sciences, Davao Oriental State University. Mati 8200, Davao Oriental, Philippines.
Tel.: +63-906-4763952, email: cirilojr.ybanez@gmail.com

Manuscript received: 14 February 2024. Revision accepted: 6 May 2024.

**Abstract.** *Ybañez JR CO. 2024. Exploring meiofaunal assemblages in Pujada Bay, Philippines: A glimpse into one of the world's most beautiful bays. Biodiversitas 25: 1946-1954.* This study explores the meiofaunal communities within Pujada Bay's intertidal zone, Philippines, meticulously recording 18,193 individuals across 18 taxa. Differences in composition and abundance across sites were observed, with conservation efforts at Guang-guang yielding higher densities (4,613 ind/10 $cm^{-2}$) compared to less-managed sites such as Magsaysay (928 ind/10 $cm^{-2}$) and Badas (1,438 ind/10 $cm^{-2}$). Furthermore, Macambol, distant from direct threats, exhibited notable densities (4,483 ind/10 $cm^{-2}$), indicating the importance of geographic isolation in ecosystem preservation. Dominant taxa include Nematoda (41%), Copepoda (28%), Foraminifera (22%), and Polychaeta (5%), underscoring their ecological significance in Pujada Bay's meiofaunal community. These findings highlight the efficacy of conservation measures in fostering resilient meiofaunal communities, where management strategies and geographic location play vital roles in biodiversity preservation. This research offers valuable insights into the ecological dynamics of Pujada Bay, emphasizing the indispensable role of conservation in maintaining biodiversity. By elucidating meiofaunal dynamics, this study advances our understanding of the local marine ecosystem and lays the groundwork for broader discussions on marine conservation strategies. Pujada Bay, considered one of the most beautiful bays in the world, exemplifies the delicate balance between human activities and the imperative of preserving biodiversity in marine environments.

**Keywords:** Abundance, ecological dynamics, meiofauna, Pujada Bay, sediments

## INTRODUCTION

Nestled along the southeastern coast of the Philippines is the protected gem of natural beauty, Pujada Bay in Davao Oriental (06°87'29.4 N, 126°22'98.9 E) (Terayama et al. 2022). Renowned for its stunning landscapes, crystal-clear waters, and vibrant marine ecosystems. Pujada Bay earned recognition by unanimously joining the prestigious Most Beautiful Bays in the World (MBBW) list during the 15th World Bays Congress in Japan in October 2019 (Ponce and Villegas 2022). Within this coastal haven lies a concealed world dominated by meiofauna, a diverse collection of small metazoans inhabiting freshwater and marine environments, acting as a crucial link between macrofauna and microbenthos (Ptatscheck et al. 2020a). Classified by size, these organisms navigate the environmental landscape, passing through 1000 µm mesh while being retained in 44 to 20 µm sieves (Ptatscheck et al. 2020b), marking their pivotal role in the intricate balance of the marine ecosystem (Schratzberger and Ingels 2017). The meiofauna community comprises 25 animal phyla, further classified into soft (e.g., Archiannelida, Ciliata) and hard (e.g., Brachiopoda, Copepoda) animals (Carugati et al. 2015).

Meiofauna plays a crucial role in the functioning of marine ecosystems (Schratzberger and Ingels 2017). Serving as foundational components, they actively participate in nutrient cycling, influencing the distribution and availability of nutrients, thereby contributing to the overall health and productivity of marine ecosystems (Wang et al. 2020). Additionally, meiofauna significantly contributes to sediment stability by burrowing and redistributing sediments, impacting the habitat for other benthic organisms and shaping the physical environment of marine areas (Moens and Beninger 2018; Schratzberger and Ingels 2017). Their pivotal role extends to the trophic food chain, where meiofauna serve as essential food sources for juvenile fish and other marine organisms, fostering the growth and development of higher trophic levels (Ptatscheck et al. 2020a). This significance creates a ripple effect throughout the marine food web, ultimately contributing to the resilience and diversity of marine ecosystems (Schratzberger et al. 2023).

In the realm of meiofauna research in the Philippines, the past decade has revealed a noticeable scarcity of studies, with only 11 conducted within this period. These studies were categorized into two groups: two studies focused on the entire meiofauna group, namely Busmion and Arche (2021) and del Norte-Campos and Burgos (2017), while the remaining nine studies concentrated on specific taxa. Nematodes were studied by Sanchez et al. (2019), Yu and Xu (2018), copepods by Cottarelli and Bruno (2021), and foraminiferans in studies by Lacuna and Gayda (2014), Unsing and Lacuna (2014), Lacuna and Alviro (2014), Ganaway and Lacuna (2014), Oñate and Lacuna (2015), and Felix et al. (2022). Among these taxa, foraminiferans emerged as the most studied group. Surprisingly, no research has been documented in the past decade focusing on meiofauna within bays, indicating a significant gap in our understanding of these ecosystems. Overall, the landscape of meiofauna studies in the Philippines remains limited, highlighting the need for further research to comprehensively explore and comprehend the country's meiofaunal communities across various marine and aquatic environments.

This research investigates the intricate relationships governing meiofaunal assemblages thriving in Pujada Bay. By delving into the microscopic realm within the bay's sediments, this study aims to uncover hidden treasures and shed light on often-overlooked inhabitants that play a crucial role in the bay's ecological resilience. Furthermore, given the scarcity of studies on meiofauna in the Philippines, this investigation becomes even more critical, filling a notable gap in scientific knowledge regarding this aspect of marine ecology. Beyond expanding our understanding of meiofaunal biodiversity, this study holds implications for broader ecological and conservation efforts. In the face of global challenges such as climate change and environmental degradation, unraveling the intricacies of meiofaunal communities in a pristine location like Pujada Bay can offer valuable insights into the resilience of coastal ecosystems. The findings have the potential to contribute to informed conservation strategies, aiding in the sustainable management of this unique and fragile ecosystem.

## MATERIALS AND METHODS

### Study area

The research was conducted at various locations within Pujada Bay, in the City of Mati, Davao Oriental, at the southeasternmost point of the Philippine archipelago on Mindanao Island (Figure 1 and Table 1). Pujada Bay has a distinctive U-shaped structure that opens toward the southeastern portion, facing the Pacific Ocean. It was designated as a Marine Protected Area (MPA) on 31 July 1994, under the National Integrated Protected Areas System (NIPAS) through Proclamation no. 431, covering an area of 21,200 hectares known as the Pujada Bay Protected Landscape and Seascape (Terayama et al. 2022).

In this study, seven distinct sites along the coastal areas of Pujada Bay were established to gain insights into coastal conservation (Figure 2). Each station provided a unique perspective on preserving these vital ecosystems. Pujada Island (S1) was observed to showcase unspoiled natural beauty, despite facing threats from human activities such as littering and overdevelopment. Masao Beach (S2) emerged as a popular tourist spot, highlighting the delicate balance required between conservation and recreation. Guang-guang (S3) was noted for its conservation management practices and efforts in biodiversity preservation. Magsaysay (S4) was found to be polluted, emphasizing the urgent need for pollution control measures and community engagement. Badas (S5) exemplified the intricate relationship between aquaculture and conservation. Balete Bay (S6) was observed to face red tide threats and fish cage proliferation, indicating the need for focused conservation efforts. Macambol (S7) was identified as a pristine wilderness, underscoring the importance of preserving untouched ecosystems and promoting sustainable development.

**Table 1.** Specimen collection data, with station numbers corresponding to those in Figure 1

| Station | Study area | Global position |
|---|---|---|
| S1 | Pujada Island | 06°47'46.1 N 126°15'26.0 E |
| S2 | Masao Beach | 06°51'56.1 N 126°17'50.1 E |
| S3 | Guang-guang | 06°54'42.6 N 126°15'36.0 E |
| S4 | Magsaysay | 06°56'57.3 N 126°13'10.2 E |
| S5 | Badas | 06°55'37.6 N 126°11'11.8 E |
| S6 | Balete Bay | 06°53'03.8 N 126°10'06.1 E |
| S7 | Macambol | 06°47'57.2 N 126°13'34.5 E |

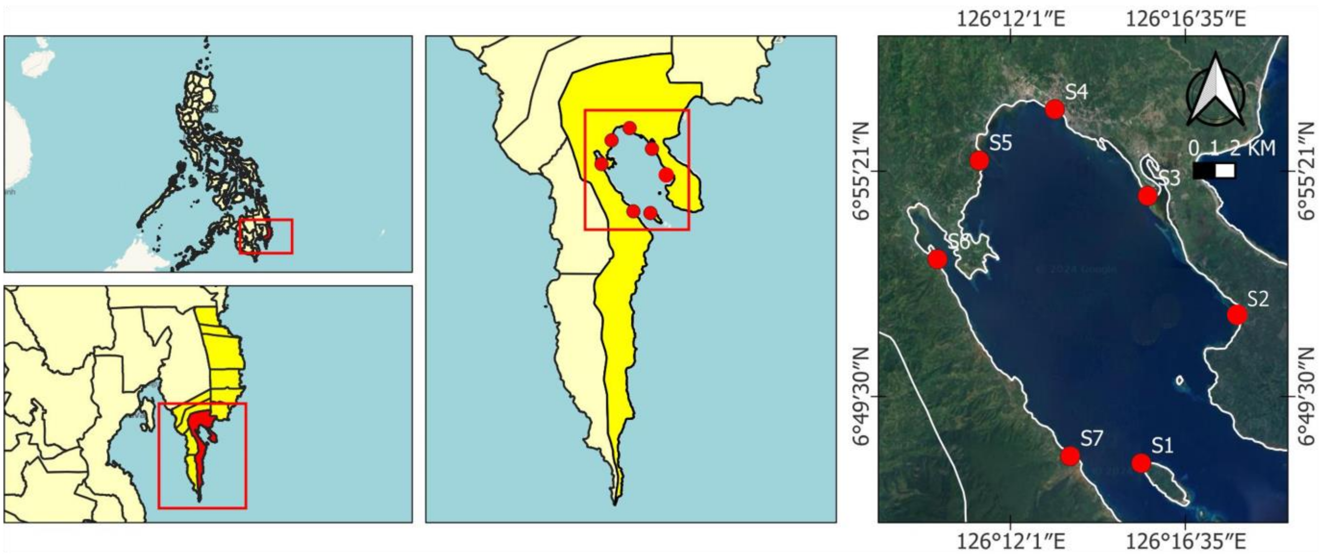


**Figure 1.** The geographical locations of study sites within Pujada Bay, Mati City, Davao Oriental, Philippines. S1: Pujada Island; S2: Masao Beach; S3: Guang-guang; S4: Magsaysay; S5: Badas; S6: Balete Bay; S7: Macambol

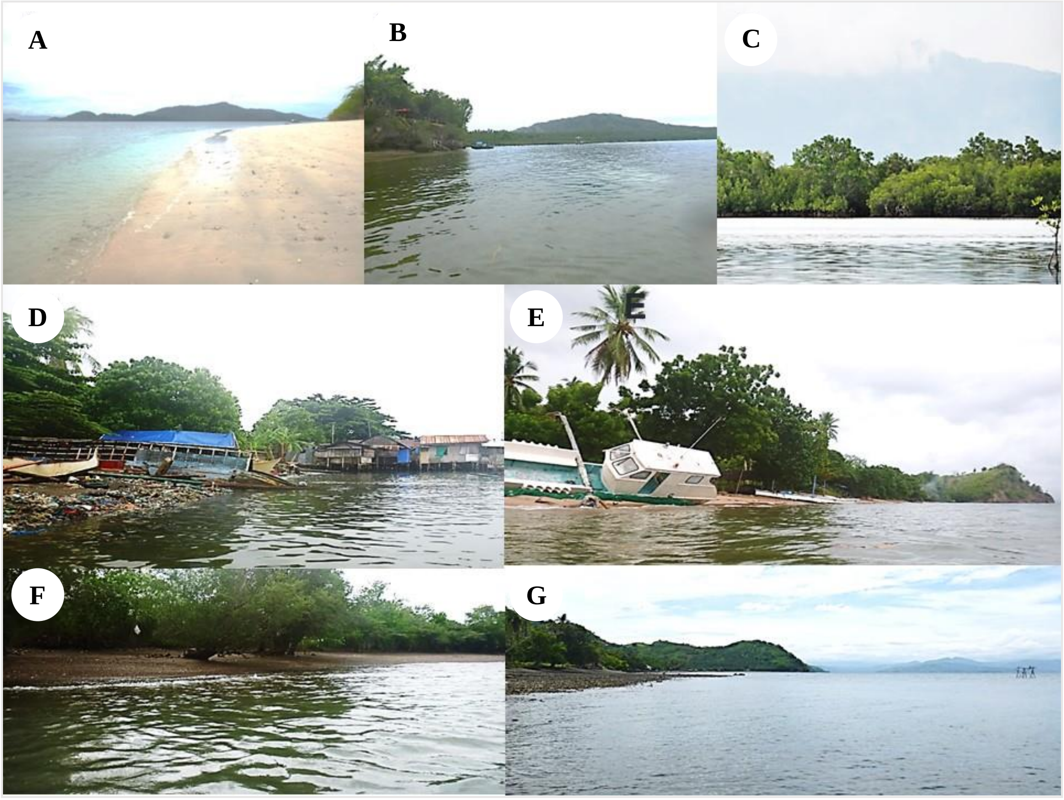


**Figure 2.** The depicts the seven research locations in Pujada Bay: A. Pujada Island; B. Masao Beach; C. Guang-guang; D. Magsaysay; E. Badas; F. Balete Bay; G. Macambol

**Sample collection**

Before commencing data collection, the researcher sought permission through formal procedures. Formal letters were submitted to both the Mati Provincial and Municipal Office in the City of Mati, Davao Oriental, outlining the nature and purpose of the research and requesting necessary approvals. A separate letter was also delivered to the Bureau of Fisheries and Aquatic Resources (BFAR) to seek entry clearance and secure the gratuitous permit (no. 0160-18), enabling the researcher to collect samples legally.

The research was conducted between September and December 2019, with sediment sample collection timed to coincide with low tide periods to optimize sampling efficacy. Seven sampling stations were strategically positioned around Pujada Bay for this purpose. A systematic approach was employed at each station, involving the placement of three 5 $m^2$ quadrats parallel to the coastline at the waterline, with a designated interval of 25 m between each quadrat. Within these quadrats, three 1 x 1 m (1 $m^2$) sub-quadrats were positioned perpendicular to the shoreline, and samples were then collected randomly from each sub-quadrat. The coring method was the primary technique for gathering meiofauna from the sediments (Montagna et al. 2017). A PVC meiocorer, featuring a diameter of 5 cm and a length of 30 cm, was utilized for obtaining sediment samples. Three random replicates were collected from inside each quadrat at a depth of 10 cm using the corer (El-Serehy et al. 2015). Therefore, to ensure the fixation of meiofauna, sediments were treated with a 4% formaldehyde solution (Mevenkamp et al. 2016) inside labeled plastic bags, indicating the respective station, quadrat, and replicate number. The samples were then carefully stored in a large box container and transported for processing at the Integrated Coastal Resources Management Project - Region XI (ICRMP RIC-XI) laboratory within the Davao Oriental State University (DOrSU). This meticulous sampling and processing approach adhered to established methodologies for meiofauna collection and preservation (Zeppilli et al. 2015).

*Meiofauna extraction*

In the laboratory, well-established decantation and sieving methods were employed to effectively separate meiofauna from the sediment matrix (Haenel et al. 2017). For the extraction of meiofauna from finer sediments, a density gradient technique utilizing Ludox TM was incorporated (Rohal et al. 2018). The collected sediment samples were initially sieved through a 1000 µm mesh to remove larger coarse sediments. Subsequently, the samples were transferred to a 1000 mL Erlenmeyer flask, and 200 mL of tap water was added to create a suspension, achieved through manual and vigorous swirling until fine particles and meiofauna were adequately suspended. The resulting supernatants were carefully sieved using a 42 µm mesh (Majdi et al. 2017). The supernatant samples underwent ten rounds of decantation to ensure further effective separation of meiofauna from sediments (Moens and Beninger 2018). Once separated, the meiofauna samples were stained using a 0.5 g $L^{-1}$ Rose Bengal solution. Each sample was placed in a 100 mL plastic bottle, ensuring full submersion in the prepared solution. The staining process involved adding enough Rose Bengal solution to cover the samples completely, and the bottles were sealed tightly to prevent evaporation and contamination (Felix et al. 2022; Schmidt et al. 2019; Mascart et al. 2015). This staining process, undertaken at least 12 hours before sorting, enhances visibility and aids in the subsequent identification and sorting of meiofaunal organisms.

*Identification, quantification, and classification*

An exhaustive analysis of the meiofauna was conducted with meticulous care and under expert guidance in meiofauna taxonomy, encompassing identification, quantification, and classification extending to the most specific taxonomic levels attainable. This intricate examination transpired beneath a stereomicroscope, employing a small gridded rectangular dish (10 × 5 cm) as the containment vessel. Photographic records of the meiofauna were systematically captured using an AmScope microscope to ensure the precision of documentation. The meiofauna underwent a scrupulous identification process based on their morphological characteristics. This involved referencing authoritative taxonomic works, namely Higgins and Thiel (1988), Giere (2009), and Schmidt-Rhaesa (2014), along with online resources such as https://www.marinespecies.org/. The amalgamation of these references facilitated a comprehensive and reliable taxonomic assignment of the identified meiofaunal specimens.

**Data analysis**

The research conducted in Pujada Bay employed a quantitative approach to gauge the population density of meiofauna. This involved dividing the total count of individuals by the volume of subsamples, which was then expressed as ind/10 $cm^{-2}$ (Baldrighi et al. 2019). This method allowed for a detailed comprehension of meiofauna density within the sediment. In assessing relative abundance, the study utilized a formula that involved dividing the number of individuals of a species in a specific taxon by the total number of individuals in the sample, then multiplying by 100%. This approach, as outlined by Zeppilli et al. (2015), enabled the quantification of species contributions, facilitating a deeper understanding of community structure and diversity. These quantitative methodologies serve as the cornerstone for delving into meiofauna ecology and are crucial in informing conservation efforts within Pujada Bay.

## RESULTS AND DISCUSSION

Moreover, 18,193 individuals representing 18 meiofauna taxa were identified in Pujada Bay, Davao Oriental, Philippines. The taxa observed included Amphipoda, Brachiopoda, Chaetognatha, Copepoda, Cumacea, Foraminifera, Gastropoda, Halacaroidea, Isopoda, Nematoda, Oligochaeta, Ostracoda, Polychaeta, Rotifera, Sipuncula, Tanaidacea, Tardigrada, and Turbellaria (Figure 3).

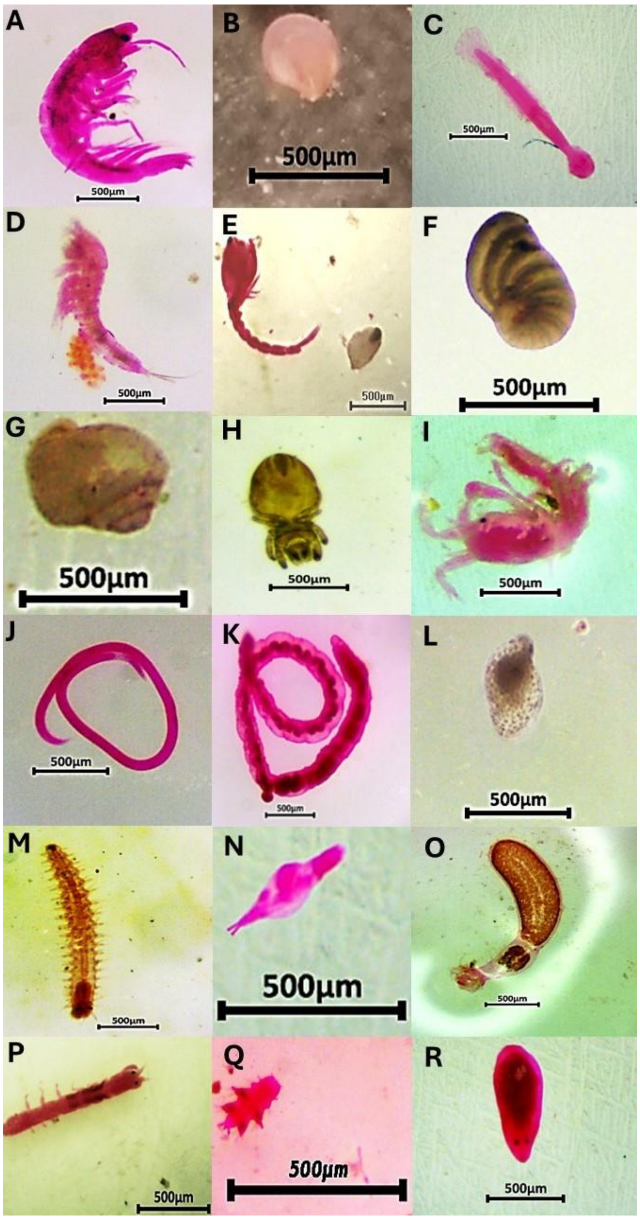


**Figure 3.** Illustrates the representatives of each meiofauna taxa observed in Pujda Bay: A. Amphipoda; B. Brachiopoda; C. Chaetognatha; D. Copepoda; E. Cumacea; F. Foraminifera; G. Gastropoda; H. Halacaroidea; I. Isopoda; J. Nematoda; K. Oligochaeta; L. Ostracoda; M. Polychaeta; N. Rotifera; O. Sipuncula; P. Tanaidacea; Q. Tardigrada; R. Turbellaria

This study uncovered variation in meiofaunal densities across the surveyed sites. Guang-guang emerged with the highest density recorded at 4,613 ind/10 $cm^{-2}$, closely trailed by Macambol at 4,483 ind/10 $cm^{-2}$ (Figure 4.A). Guang-guang's status as a protected area may have played a pivotal role in explaining its remarkably high meiofaunal density. The stringent conservation measures implemented within Guang-guang minimize direct anthropogenic disturbances and create an environment conducive to the flourishing of meiofaunal populations. Reduced pollution, limited human interference, and careful management practices contribute to maintaining optimal habitat conditions, thus allowing meiofauna to thrive. Consequently, Guang-guang is a prime example of how effective protection protocols can bolster biodiversity and ecological resilience within coastal ecosystems.

In Guang-guang, conservation efforts encompass a multifaceted approach aimed at preserving marine ecosystems. Central to these endeavors is (i) biodiversity conservation, which targets the protection and enhancement of habitats for various species inhabiting the region's mangroves, seagrass beds, and coral reefs. Complementing this initiative is (ii) water quality management, which is pivotal in safeguarding ecosystem and species health through rigorous monitoring and improvement of area water quality. Concurrently, (iii) mangrove reforestation initiatives are underway, seeking to restore and expand these vital forests to provide indispensable habitats for marine organisms while bolstering coastal defense mechanisms. Moreover, (iv) community involvement plays a pivotal role in these conservation efforts, with locals engaged through educational campaigns, awareness programs, and sustainable livelihood initiatives. Finally, (v) ecotourism promotion endeavors to strike a delicate balance between fostering an appreciation for the inherent beauty of the Guang-guang ecosystem and mitigating potential environmental impacts through the advocacy of responsible tourism practices.

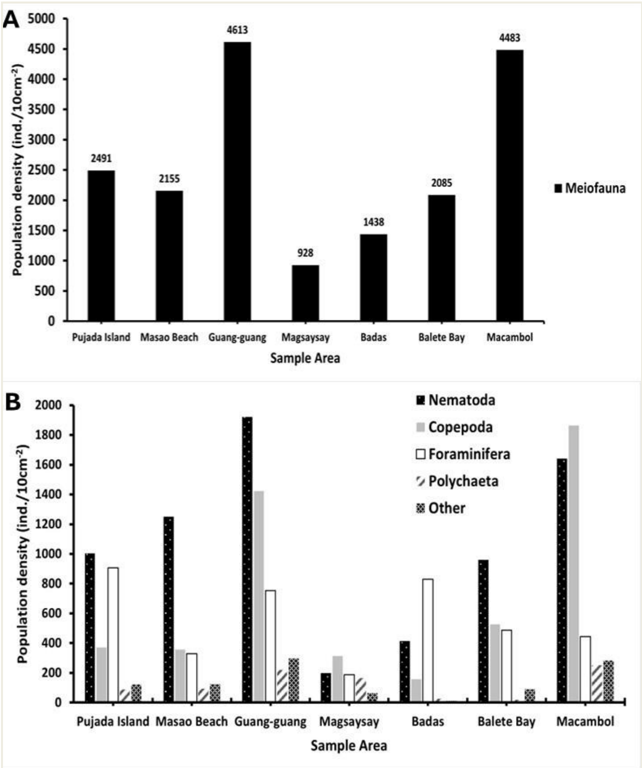


**Figure 4.** Population density profiles: A. Spatial distribution of meiofauna; B. Taxonomic composition of meiofauna in Pujada Bay, Davao Oriental, Philippines

Macambol, nestled far from human habitation and embodying pristine wilderness, is a pivotal site for preserving untouched ecosystems. Its remote location underscores the imperative of advocating for balanced conservation approaches that prioritize both biodiversity protection and sustainable development. Research by Ingels et al. (2023b) delves into the meiobenthos, including meiofauna, of the deep Arctic Ocean, emphasizing the elevated densities of meiofauna in pristine deep-sea environments. However, it is crucial to recognize that even remote areas like Macambol are not entirely immune to anthropogenic impacts, as indirect pressures from climate change persist. Consequently, continued monitoring and conservation efforts are imperative to safeguard the ecological integrity of coastal habitats.

The higher density of meiofauna in areas of high conservation and geographical isolation, in contrast to regions plagued by pollution and human habitation, can be attributed to several factors. Reduced anthropogenic disturbance (Pulido-Chadid et al. 2023), evident in less disturbed or undisturbed environments, fosters more favorable conditions for meiofaunal populations to thrive (Semprucci et al. 2015). Additionally, higher habitat quality in these areas, characterized by cleaner water and more stable environmental conditions, facilitates higher population densities and biodiversity (Baldrighi and Manini 2015). Lower predation pressure and altered food availability further contribute to the disparity in meiofaunal densities (Schratzberger and Somerfield 2020).

In contrast, Magsaysay and Badas exhibited notably lower meiofaunal densities (928 ind/10 $cm^{-2}$ and 1,438 ind/10 $cm^{-2}$, respectively), indicating potential environmental degradation in these areas (Figure 4A). Magsaysay's proximity to coastal settlements accentuates pollution pressures, necessitating urgent pollution control measures and community engagement initiatives. These findings emphasize the urgency of proactive environmental management to mitigate anthropogenic impacts and preserve coastal ecosystem health. Notably, studies by Schratzberger and Somerfield (2020), Gambi et al. (2020), Kim et al. (2020), Baldrighi et al. (2019), Bertocci et al. (2019), and Sun et al. (2014) provide insights into meiofauna's ecological significance, their use as bio-indicators, and the factors influencing their abundance and diversity, particularly in the context of human disturbances and the observed changes in meiofauna density under anthropogenic threats.

The variation in the most abundant taxon of meiofauna across different stations raises intriguing questions regarding ecological dynamics and environmental conditions. In environments where nematodes dominate, such as Pujada Island (1,004 ind/10 $cm^{-2}$), Masao Beach (1,251 ind/10 $cm^{-2}$), Guang-guang (1,920 ind/10 $cm^{-2}$), Balete Bay (961 ind/10 $cm^{-2}$), and Macambol (1,641 ind/10 $cm^{-2}$) (Figure 4.B), it suggests favorable conditions for nematode proliferation. Nematodes are known for their adaptability to various environmental conditions, including varying levels of organic enrichment and sediment types (Boufahja et al. 2016). Their high densities at these stations may indicate stable and nutrient-rich sediment conditions, supporting robust nematode populations. The dominance of nematodes in these environments could be attributed to their ability to exploit available resources efficiently. Nematodes have diverse feeding strategies, allowing them to thrive in environments with different levels of organic matter availability (Schuelke et al. 2018). Furthermore, their small size and high reproductive rates enable them to colonize and proliferate in favorable conditions quickly (Ptatscheck and Traunspurger 2020). The prevalence of nematodes in these stations highlights the importance of understanding the mechanisms driving their abundance and distribution in marine sediments.

Conversely, stations like Macambol (1,864 ind/10 $cm^{-2}$) and Magsaysay (313 ind/10 $cm^{-2}$), where copepods are the most abundant taxon (Figure 4.B), may exhibit different environmental characteristics. Copepods are often associated with areas of higher water column productivity and phytoplankton blooms (Friedland et al. 2016). Thus, their dominance at these stations could reflect a different trophic regime or hydrodynamic conditions, potentially influenced by nutrient availability, water column stability, and primary productivity; the presence of copepods as the dominant taxon suggests a link between meiofaunal composition and broader ecosystem dynamics. Copepods play essential roles in marine food webs, serving as prey for various organisms and contributing to nutrient cycling (Feng et al. 2023). Understanding the environmental factors driving their abundance can provide insights into ecosystem functioning and stability.

The presence of foraminiferans as the most abundant taxon in Balete Bay (829 ind/10 $cm^{-2}$) adds further complexity to the discussion (Figure 4.B). Foraminiferans, characterized by their calcium carbonate tests, are sensitive to changes in water chemistry and sediment conditions (Prazeres et al. 2020). Their dominance in Balete Bay may signify specific environmental conditions favoring their growth, potentially related to water chemistry parameters such as pH, carbonate saturation, or sediment composition. The prevalence of foraminiferans in Balete Bay stresses the importance of considering the interactive effects of multiple environmental variables on meiofaunal communities. Changes in water chemistry, sediment composition, and other factors can influence the distribution and abundance of foraminiferans, highlighting their potential as indicators of environmental change.

The variation in the most abundant meiofaunal taxa across different stations underscores the importance of considering the multifaceted interactions between environmental factors and meiofaunal community composition. Further investigation into the specific environmental drivers shaping meiofaunal communities at each station could provide valuable insights into ecosystem dynamics and inform conservation and management strategies tailored to each unique habitat. However, despite identifying numerous meiofaunal patterns and relationships, fundamental questions persist regarding their existence, formation, and maintenance, as highlighted by Ingels et al. (2023a). The ongoing lack of answers to questions such as why these patterns exist and how they are formed emphasizes the ongoing challenges in meiofaunal research. Despite advancements, limited progress has been made in understanding these crucial aspects of meiofaunal ecology. Therefore, further research is imperative to unravel the complexities of meiofaunal dynamics and their implications for marine ecosystems.

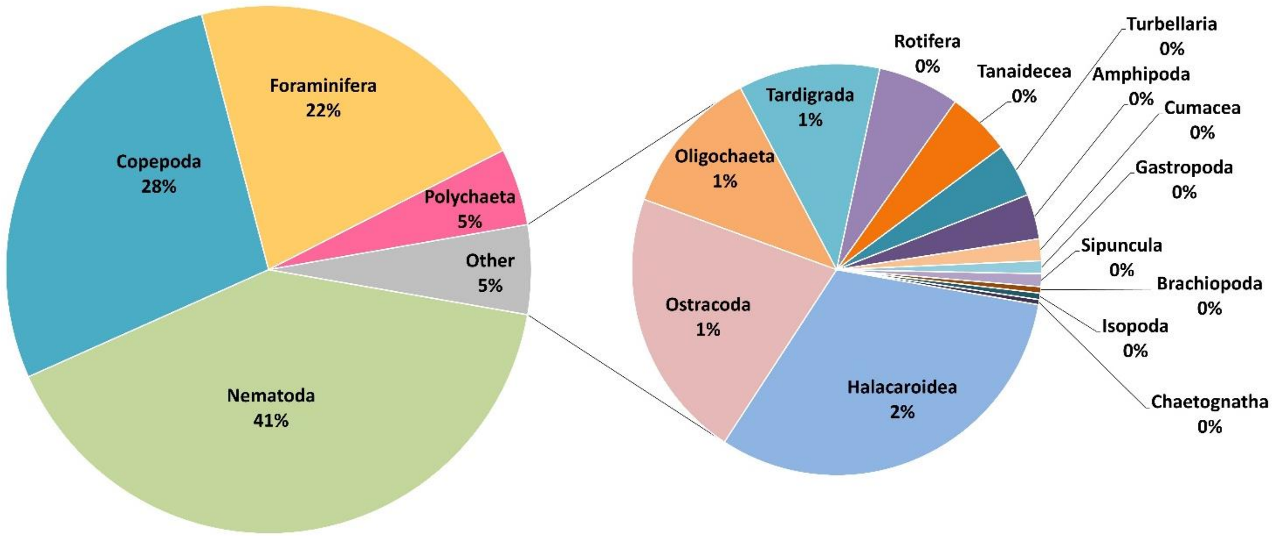


**Figure 5.** The illustration on the relative abundance of meiofauna in Pujada Bay, Davao Oriental, Philippines

The taxonomic composition of meiofaunal communities in Pujada Bay showcases the dominance of key taxa, with Nematoda comprising 41%, Copepoda 28%, Foraminifera 22%, and Polychaeta 5% (Figure 5). Taxa representing less than 3% were grouped as "other," accounting for 5% of the total meiofaunal species. The prevalence of these dominant taxa underscores their ecological significance in ecosystem processes. Nematodes, characterized by diverse feeding habits and prolific reproductive rates, often dominate marine sediment communities, crucial for organic matter decomposition and nutrient cycling (Du et al. 2014). Similarly, copepods, foraminifera, and polychaetes play integral roles as grazers (Jagadeesan et al. 2017), detritivores (Burone et al. 2021), and predators (Cuevas et al. 2018), contributing to energy flow and nutrient dynamics within benthic ecosystems. The categorization of taxa representing less than 3% as "other" highlights the presence of rare or less abundant species, which could contribute significantly to ecosystem functioning and biodiversity. Future studies on these taxa could provide valuable insights into their ecological roles and interactions within meiofaunal communities.

The findings concerning the most dominant taxa are consistent with previous global studies on meiofauna. Zeppilli et al. (2018) highlight the prevalence of nematodes and copepods in unique habitats, emphasizing their adaptability and ecological importance in extreme environments. Wang et al. (2019) specifically emphasize the predominance of marine nematodes and benthic copepods in the Western Pacific Ocean, particularly in deep-sea ecosystems adjacent to the Yap Trench. In Jiaozhou Bay, China, Gao and Liu (2018) have identified free-living marine nematodes as the most dominant meiofaunal group, followed by benthic copepods. Likewise, Kim et al. (2023) noted nematodes and polychaetes as the most dominant meiofaunal taxa along the Korean coast, although their dominance varied across stations. Lins et al. (2014) found nematodes to dominate the meiofauna in the Southern Ocean, while in the Chukchi Sea, nematodes represented 96.6 to 98.90% of the total meiofaunal abundance across shallow water and deep-sea stations. In Krossfjord, Svalbard Archipelago, Jima et al. (2023) identified living foraminiferans as a prominent component of this community, highlighting the richness and diversity in this region.

The study encountered challenges in precisely identifying invasive species, primarily due to limitations in sample identification at the species level. Despite these obstacles, the study emphasizes the importance of addressing invasive species in future research. With advancements in methodologies and facilities, the goal is to incorporate invasive species identification into future investigations of meiofauna. This integration will allow for a more comprehensive evaluation of their potential impact on the ecological balance of Pujada Bay's meiofaunal community.

**Implications and conclusion**

The study underscores the importance of conservation efforts in maintaining resilient meiofaunal communities. Sites with stricter conservation management, such as Guang-guang, exhibited higher meiofaunal densities, highlighting the efficacy of protection protocols. This implies that prioritizing conservation measures can positively impact meiofaunal biodiversity, contributing to the overall health of marine ecosystems. Geographic isolation, exemplified by Macambol, plays a significant role in preserving biodiversity. Despite its remote location, Macambol exhibited notable meiofaunal densities, indicating the importance of advocating for balanced conservation approaches that prioritize both biodiversity protection and sustainable development in untouched ecosystems.

Lower meiofaunal densities in areas like Magsaysay and Badas, which face pollution and human habitation pressures, highlight the urgent need for pollution control measures and community engagement initiatives. Proactive environmental management is imperative to mitigate anthropogenic impacts and preserve coastal ecosystem health. Understanding meiofaunal dynamics provides insights into the resilience of coastal ecosystems. By elucidating the intricate relationships governing meiofaunal diversity, this research informs broader ecological discussions and aids in developing informed conservation strategies to address global challenges such as climate change and environmental degradation.

The study sheds light on the meiofaunal communities thriving in Pujada Bay, Philippines, offering valuable insights into their composition, abundance, and ecological dynamics. Significant variations in meiofaunal densities across sites highlight the influence of conservation measures and geographic isolation on biodiversity preservation. Dominant taxa such as Nematoda, Copepoda, Foraminifera, and Polychaeta underscore their ecological significance in marine ecosystems. These findings emphasize the critical role of conservation in maintaining resilient meiofaunal communities and preserving biodiversity in marine environments. This research contributes to broader discussions on marine conservation strategies by advancing our understanding of meiofaunal dynamics. Pujada Bay celebrated as one of the most beautiful bays in the world, serves as a prime example of the intricate interplay between human activities and the essential need to conserve biodiversity in coastal habitats. Efforts to protect and sustainably manage coastal ecosystems are essential for safeguarding their ecological integrity and resilience in global environmental challenges.

To advance the understanding of meiofaunal communities within Philippine bays, several strategic approaches are proposed. Firstly, enhancing studies with larger sample sizes and broader spatial coverage would provide a more comprehensive depiction of meiofaunal diversity and distribution patterns. Implementation of long-term monitoring programs could facilitate the tracking of meiofaunal communities over time, elucidating trends, seasonal dynamics, and responses to environmental changes, both natural and anthropogenic. Molecular techniques, notably DNA barcoding, could significantly improve the accuracy of species identification, thereby overcoming challenges associated with morphological identification and offering insights into genetic diversity, evolutionary relationships, and the detection of invasive species. Furthermore, the application of environmental DNA (eDNA) analysis stands out as a promising avenue to detect and quantify meiofaunal species in environmental samples, offering valuable insights into community composition and distribution without invasive sampling methods.

## ACKNOWLEDGEMENTS

The researcher extends their sincere appreciation to Dr. Lea A. Jimenez and the team at ICRMP RIC-XI for their invaluable support and for granting permission to utilize their top-notch lab facilities for analyzing meiofauna samples. Additionally, the researcher wants to express deep gratitude to Harold C. Malintad for his assistance during field sampling and sample processing of meiofauna, and to Rolando C. Balaquit for generously providing access to microscope facilities at DOrSU, which significantly aided in the detailed analysis process.

## REFERENCES

Baldrighi E, Grall J, Quillien N, Carriço R, Verdon V, Zeppilli D. 2019. Meiofauna communities' response to an anthropogenic pressure: The case study of green macroalgal bloom on sandy beach in Brittany. Estuar Coast Shelf Sci 227: 106326. DOI: 10.1016/j.ecss.2019.106326.

Baldrighi E, Manini E. 2015. Deep-sea meiofauna and macrofauna diversity and functional diversity: Are they related? Mar Biodivers 45: 469-488. DOI: 10.1007/s12526-015-0333-9.

Bertocci I, Dell'Anno A, Musco L, Gambi C, Saggiomo V, Cannavacciuolo M, Martire ML, Passarelli A, Zazo G, Danovaro R. 2019. Multiple human pressures in coastal habitats: Variation of meiofaunal assemblages associated with sewage discharge in a post-industrial area. Sci Total Environ 655: 1218-1231. DOI: 10.1016/j.scitotenv.2018.11.121.

Boufahja F, Semprucci F, Beyrem H. 2016. An experimental protocol to select nematode species from an entire community using progressive sedimentary enrichment. Ecol Indic 60: 292-309. DOI: 10.1016/j.ecolind.2015.07.002.

Burone L, Franco-Fraguas P, Carranza A, Calliari D, Michaelovitch de Mahiques M, Gómez M, Marin Y, Gutiérrez O, Ortega L. 2021. Physical drivers and dominant oceanographic processes on the Uruguayan margin (Southwestern Atlantic): A review and a conceptual model. J Mar Sci Eng 9 (3): 304. DOI: 10.3390/jmse9030304.

Busmion KN, Arche NC. 2021. Meiofauna diversity in the littoral zone of Lake Balinsasayao, Sibulan, Negros Oriental, Philippines. AIP Conf Proc 2331 (1): 050016. DOI: 10.1063/5.0041795.

Carugati L, Corinaldesi C, Dell'Anno A, Danovaro R. 2015. Metagenetic tools for the census of marine meiofaunal biodiversity: An overview. Mar Genom 24: 11-20. DOI: 10.1016/j.margen.2015.04.010.

Cottarelli V, Bruno MC. 2021. Interesting interstitial Paramesochridae (Copepoda: Harpacticoida): *Maliithipon wellsi* gen. et sp. nov. from the Philippines, *M. aberrans* (Mielke, 1984) comb. nov. from Panama, and *M. cf. aberrans* (Mielke, 1984) from the Azores. Zootaxa 5051 (1): 68-93. DOI: 10.11646/zootaxa.5051.1.7.

Cuevas N, Martins M, Rodrigo AP, Martins C, Costa PM. 2018. Explorations on the ecological role of toxin secretion and delivery in jawless predatory Polychaeta. Sci Rep 8 (1): 7635. DOI: 10.1038/s41598-018-26031-1.

del Norte-Campos AG, Burgos LA. 2017. The meiofaunal assemblages of rocky shore site in the Taklong Island National Marine Reserve, Southern Guimaras, West Central Philippines. Philippine Agric Sci 100 (2): 125-132.

Du Y, Gao S, Warwick RM, Hua E. 2014. Ecological functioning of free-living marine nematodes in coastal wetlands: an overview. Chin Sci Bull 59: 4692-4704. DOI: 10.1007/s11434-014-0592-z.

El-Serehy HA, Al-Misned FA, Al-Rasheid KA. 2015. Population fluctuation and vertical distribution of meiofauna in the Red Sea interstitial environment. Saudi J Biol Sci 22 (4): 459-465. DOI: 10.1016/j.sjbs.2015.02.018.

Felix M, Ybañez Jr C, Macusi E. 2022. Assemblages of benthic foraminifera in Pujada Island, Davao Oriental, Philippines. Davao Res J 13 (1): 91-111. DOI: 10.59120/drj.v13i1.92.

Feng J, Mazzei M, Di Gregorio S, Niccolini L, Vitiello V, Ye Y, Guo B, Yan X, Buttino I. 2023. Marine copepods as a microbiome hotspot: Revealing their interactions and biotechnological applications. Water 15 (24): 4203. DOI: 10.3390/w15244203.

Friedland KD, Record NR, Asch RG, Kristiansen T, Saba VS, Drinkwater KF, Henson S, Leaf RT, Morse RE, Johns DG, Large SI, Hjøllo SS, Nye JA, Alexander MA, Ji R. 2016. Seasonal phytoplankton blooms in the North Atlantic linked to the overwintering strategies of copepods. Elementa 4: 000099. DOI: 10.12952/journal.elementa.000099.

Gambi C, Dell'Anno A, Corinaldesi C, Martire ML, Musco L, Da Ros Z, Armiento G, Danovaro R. 2020. Impact of historical contamination on meiofaunal assemblages: The case study of the Bagnoli-Coroglio Bay (southern Tyrrhenian Sea). Mar Environ Res 156: 104907. DOI: 10.1016/j.marenvres.2020.104907.

Ganaway SM, Lacuna ML. 2014. Benthic foraminifera in moderately polluted coasts of Iligan City, Philippines: Diversity and abundance. Anim Biol Anim Husb 6 (1): 34-49.

Gao C, Liu X. 2018. Spatio-temporal distribution of meiofaunal assemblages and its relationship with environmental factors in a semi-enclosed bay. Mar Pollut Bull 131: 45-52. DOI: 10.1016/j.marpolbul.2018.03.047.

Giere O. 2009. Meiofauna taxa: A systematic account. In: Meiobenthology. Springer, Berlin, Heidelberg. DOI: 10.1007/978-3-540-68661-3_5.

Haenel Q, Holovachov O, Jondelius U, Sundberg P, Bourlat SJ. 2017. NGS-based biodiversity and community structure analysis of meiofaunal eukaryotes in shell sand from Hållö island, Smögen, and soft mud from Gullmarn Fjord, Sweden. Biodivers Data J (5): e12731. DOI: 10.3897/BDJ.5.e12731.

Higgins RP, Thiel H. 1988. Introduction to the study of meiofauna. Smithsonian Institution Press.

Ingels J, Hasemann C, Soltwedel T, Vanreusel A. 2023a. Polar meiofauna—antipoles or parallels? In New Horizons in Meiobenthos Research: Profiles, Patterns and Potentials (pp. 285-327). Springer International Publishing, Cham. DOI: 10.1007/978-3-031-21622-0_9.

Ingels J, Leduc D, Zeppilli D, Vanreusel A. 2023b. Deep-sea meiofauna—a world on its own or deeply connected?. In New Horizons in Meiobenthos Research: Profiles, Patterns and Potentials (pp. 257-283). Springer International Publishing, Cham. DOI: 10.1007/978-3-031-21622-0_8.

Jagadeesan L, Jyothibabu R, Arunpandi N, Parthasarathi S. 2017. Copepod grazing and their impact on phytoplankton standing stock and production in a tropical coastal water during the different seasons. Environ Monit Assess 189 (105): 1-21. DOI: 10.1007/s10661-017-5804-y.

Jima M, Jayachandran PR, Rojin J, Anulakshmi N, Aswathy NK, Nandan SB, Harikrishnan M. 2023. Assessing the spatial distribution of meiofaunal communities in Krossfjord, Svalbard Archipelago: Foraminifera diversity as a key component. Reg Stud Mar Sci 66: 103153. DOI: 10.1016/j.rsma.2023.103153.

Kim H-G, Song SJ, Bae H, Noh J, Lee C, Kwon B-O, Lee J-H, Ryu J, Khim JS. 2020. Natural and anthropogenic impacts on long-term meiobenthic communities in two contrasting nearshore habitats. Environ Intl 134: 105200. DOI: 10.1016/j.envint.2019.105200.

Kim JW, Kim H-G, Kim H, Hawkins SJ, Seo I-S, Oh C-W. 2023. Spatial distribution of meiofaunal and macrofaunal assemblages in the tidal flats of the Southern Korean coast in relation to natural and anthropogenic impacts. Mar Pollut Bull 194: 115377. DOI: 10.1016/j.marpolbul.2023.115377.

Lacuna ML, Alviro MP. 2014. Diversity and abundance of benthic foraminifera in nearshore sediments of Iligan City, Northern Mindanao, Philippines. Anim Biol Anim Husb 6 (1): 1-10.

Lacuna ML, Gayda KA. 2014. Benthic foraminiferal assemblage on a mixed stands of seagrass and macroalgae in Kauswagan, Lanao del Norte, Southern Philippines. Anim Biol Anim Husb 6 (1): 102-116.

Lins L, Guilini K, Veit-Köhler G, Hauquier F, Alves RMS, Esteves AM, Vanreusel A. 2014. The link between meiofauna and surface productivity in the Southern Ocean. Deep Sea Res Part II: Trop Stud Oceanogr 108: 60-68. DOI: 10.1016/j.dsr2.2014.05.003.

Majdi N, Threis I, Traunspurger W. 2017. It's the little things that count: Meiofaunal density and production in the sediment of two headwater streams. Limnol Oceanogr 62 (1): 151-163. DOI: 10.1002/lno.10382.

Mascart T, Lepoint G, Deschoemaeker S, Binard M, Remy F, De Troch M. 2015. Seasonal variability of meiofauna, especially harpacticoid copepods, in *Posidonia oceanica* macrophytodetritus accumulations. J Sea Res 95: 149-160. DOI: 10.1016/j.seares.2014.07.009.

Mevenkamp L, Van Campenhout J, Vanreusel A. 2016. Experimental evidence for selective settlement of meiofauna from two distinct environments after sediment suspension. J Exp Marine Biol Ecol 474: 195-203. DOI: 10.1016/j.jembe.2015.10.005.

Moens T, Beninger PG. 2018. Meiofauna: An inconspicuous but important player in mudflat ecology. Mudflat Ecol 2018: 91-147. DOI: 10.1007/978-3-319-99194-8_5.

Montagna PA, Baguley JG, Hsiang C-Y, Reuscher MG. 2017. Comparison of sampling methods for deep-sea infauna. Limnol Oceanogr: Methods 15 (2): 166-183. DOI: 10.1002/lom3.10150.

Oñate CP, Lacuna ML. 2015. Benthic foraminifera in Tantanang Bay, Zamboanga Sibugay, Southern Philippines. Aquac Aquarium Conserv Legislation 8 (3): 310-322.

Ponce RG, Villegas JP. 2022. Beyond sustainability: Positioning regenerative futures in a Philippine State University. Discourse Commun Sustain Educ 13 (2): 5-12. DOI: 10.2478/dcse-2022-0014.

Prazeres M, Martínez-Colón M, Hallock P. 2020. Foraminifera as bioindicators of water quality: The FoRAM Index revisited. Environ Pollut 257: 113612. DOI: 10.1016/j.envpol.2019.113612.

Ptatscheck C, Brüchner-Hüttemann H, Kreuzinger-Janik B, Weber S, Traunspurger W. 2020a. Are meiofauna a standard meal for macroinvertebrates and juvenile fish? Hydrobiologia 847: 2755-2778. DOI: 10.1007/s10750-020-04189-y.

Ptatscheck C, Gehner S, Traunspurger W. 2020b. Should we redefine meiofaunal organisms? The impact of mesh size on collection of meiofauna with special regard to nematodes. Aquat Ecol 54: 1135-1143. DOI: 10.1007/s10452-020-09798-2.

Ptatscheck C, Traunspurger W. 2020. The ability to get everywhere: Dispersal modes of free-living, aquatic nematodes. Hydrobiologia 847 (17): 3519-3547. DOI: 10.1007/s10750-020-04373-0.

Pulido-Chadid K, Virtanen E, Geldmann J. 2023. How effective are protected areas for reducing threats to biodiversity? A systematic review protocol. Environ Evidence 12 (1): 18. DOI: 10.1186/s13750-023-00311-4.

Rohal M, Thistle D, Easton EE. 2018. Extraction of metazoan meiofauna from muddy deep-sea samples: Operator and taxon effects on efficiency. J Exp Mar Biol Ecol 502: 105-110. DOI: 10.1016/j.jembe.2017.01.006.

Sanchez KAS, Campos WL, del Norte-Campos AG, Genevieve J. 2019. Distribution of free-living nematodes in a tidal flat of Banate Bay, Iloilo, Philippines. Philippine J Nat Sci 24: 57-65.

Schmidt C, Sattarova VV, Katrynski L, Arbizu PM. 2019. New insights from the deep: Meiofauna in the Kuril-Kamchatka Trench and adjacent abyssal plain. Prog Oceanogr 173: 192-207. DOI: 10.1016/j.pocean.2019.02.010.

Schmidt-Rhaesa A. 2014. Handbook of zoology. Gastrotricha, cycloneuralia and gnathifera. Nematoda, Belgium: De Gruter.

Schratzberger M, Danovaro R, Ingels J, Montagna PA, Lupher MR, Semprucci F, Somerfield PJ. 2023. Hidden players—meiofauna mediate ecosystem effects of anthropogenic disturbances in the ocean. In New Horizons in Meiobenthos Research: Profiles, Patterns and Potentials (pp. 175-255). Springer International Publishing, Cham. DOI: 10.1007/978-3-031-21622-0_7.

Schratzberger M, Ingels J. 2017. Meiofauna matters: The roles of meiofauna in benthic ecosystems. J Exp Mar Biol Ecol 502: 12-25. DOI: 10.1016/j.jembe.2017.01.007.

Schratzberger M, Somerfield PJ. 2020. Effects of widespread human disturbances in the marine environment suggest a new agenda for meiofauna research is needed. Sci Total Environ 728: 138435. DOI: 10.1016/j.scitotenv.2020.138435.

Schuelke T, Pereira TJ, Hardy SM, Bik HM. 2018. Nematode-associated microbial taxa do not correlate with host phylogeny, geographic region or feeding morphology in marine sediment habitats. Mol Ecol 27 (8): 1930-1951. DOI: 10.1111/mec.14539.

Semprucci F, Frontalini F, Sbrocca C, Du Châtelet EA, Bout-Roumazeilles V, Coccioni R, Balsamo M. 2015. Meiobenthos and free-living nematodes as tools for biomonitoring environments affected by riverine impact. Environ Monit Assess 187 (251): 1-19. DOI: 10.1007/s10661-015-4493-7.

Sun X, Zhou H, Hua E, Xu S, Cong B, Zhang Z. 2014. Meiofauna and its sedimentary environment as an integrated indication of anthropogenic disturbance to sandy beach ecosystems. Mar Pollut Bull 88 (1-2): 260-267. DOI: 10.1016/j.marpolbul.2014.08.033.

Terayama K, Mizuno K, Tabeta S, Sakamoto S, Sugimoto Y, Sugimoto K, Fukami H, Sakagami M, Jimenez LA. 2022. Cost-effective seafloor habitat mapping using a portable speedy sea scanner and deep-learning-based segmentation: A sea trial at Pujada Bay, Philippines. Methods Ecol Evol 13 (2): 339-345. DOI: 10.1111/2041-210X.13744.

Unsing HM, Lacuna ML. 2014. Assemblages of benthic foraminifera in front of three industries along the coast of Iligan City, Southern Philippines and its relation to some environmental parameters. Adv Environ Sci 6 (2): 168-182.

Wang F, Lin D, Li W, Dou P, Han L, Huang M, Qian S, Yao J. 2020. Meiofauna promotes litter decomposition in stream ecosystems depending on leaf species. Ecol Evol 10 (17): 9257-9270. DOI: 10.1002/ece3.6610.

Wang X, Liu X, Xu J. 2019. Distribution patterns of meiofauna assemblages and their relationship with environmental factors of deep sea adjacent to the Yap Trench, Western Pacific Ocean. Front Mar Sci 6: 735. DOI: 10.3389/fmars.2019.00735.

Yu T, Xu K. 2018. Two new oxystominid species (Nematoda: Enoplida) from an abyssal plain in the southern Philippine Sea. J Mar Biol Assoc U K 98 (4): 801-810. DOI: 10.1017/S0025315417000042.

Zeppilli D, Leduc D, Fontanier C, et al. 2018. Characteristics of meiofauna in extreme marine ecosystems: A review. Mar Biodivers 48: 35-71. DOI: 10.1007/s12526-017-0815-z.

Zeppilli D, Sarrazin J, Leduc D, et al. 2015. Is the meiofauna a good indicator for climate change and anthropogenic impacts? Mar Biodivers 45: 505-535. DOI: 10.1007/s12526-015-0359-z.