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Editorial

Ecology and Biogeography of Marine Benthos

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The ocean floor, which spans approximately 71% of the Earth's surface, stretches from sunlit shallow waters to the profound depths of ocean trenches around 11,000 m deep, encompassing regions from the polar ice to tropical seas [1]. This immense and recondite realm is home to an extraordinary variety of habitats, including soft sediments, rocky and coral reefs, hydrothermal vents, mud volcanoes, and seagrass meadows [2]. The conservation of these benthic ecosystems is not merely important; it is vital, as they provide indispensable resources and services such as pollution control, food supply, raw materials, nutrient cycling, nurseries for diverse species, water quality maintenance, and the preservation of biodiversity [3].

In the face of escalating challenges like global warming and other human-induced and natural threats—including illegal fishing or invasive species [4]—it has never been more crucial to adopt ecosystem-based strategies for conserving and managing the marine environment [5,6]. However, despite the importance of these ecosystems and the threats they face, only about a quarter of the ocean floor has been mapped with (only) bathymetric information [7]. In alignment with the goals of the United Nations Decade of Ocean Sciences for Sustainable Development (2021–2030) [8] and Sustainable Development Goal 14, "Life below water" [9], this Special Issue was launched to deepen our understanding of the ecology and biogeography of these vital marine ecosystems.

In the first article of this Special Issue, Lourido et al. [10] investigated the Avilés Canyon System (ACS) on the northern Atlantic coast of Spain to identify areas of special conservation interest. Their study involved three surveys aimed at understanding the composition and distribution of organisms and habitats within this region. These researchers observed predominantly sandy sediments, with finer, organic-rich sediments in deeper areas and coarser sediments in shallower stations. Polychaetes were found to be the most abundant and diverse faunal group, followed by crustaceans and mollusks. This study identified five major macrobenthic communities, which were primarily influenced by depth and sediment type, offering considerable insight into the infaunal assemblages of the ACS.

Vesal et al. [11] examined the effects of different sources of organic matter—terrigenous/freshwater allochthonous inputs and sewage—on the activity of soft-bottom communities. They sampled macrofauna from two areas: in front of the Po River delta and a sewage discharge zone in the Gulf of Trieste (Adriatic Sea, Italy). This study revealed higher bioturbation indices at the northern sampling stations of the prodelta and at stations located 25 m from the main sewage outfall. Species diversity was notably higher in the prodelta and increased with distance from the outfall. These authors concluded that the observed differences in bioturbation across these areas were primarily attributable to variations in sediment type and levels of organic enrichment. This study provides substantial insights into the effective management and sustainable utilization of coastal resources, particularly in regions significantly affected by human activities.

Shan et al. [12] reported the arrival of the bivalve *Pinctada fucata* at Mischief Reef (Nansha Islands, South China Sea), a species previously unrecorded in this region, likely due to human activities. Genetic analysis of seven South China Sea populations suggested that Lingshui (Hainan Island) could be a source of *P. fucata* at Mischief Reef. This finding

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highlights the impact of human activities on marine ecosystems and underscores the urgent need for management strategies to prevent the introduction of additional invasive species.

Carreira-Flores et al. [13] investigated the efficacy of artificial substrates, specifically the Artificial Seaweed Monitoring System (ASMS), for assessing natural variability in assemblages over large spatial scales. This study employed the ASMS to monitor macrofauna along a 200-km stretch of the Galician Coast over 3, 6, 9, and 12 months. The results revealed differences in macrofauna assemblages between locations, supporting the theory that benthic community succession is not linear but involves a blend of different successional stages. The ASMS demonstrated its effectiveness in capturing scale-dependent patterns and temporal variability, proving to be a valuable tool for non-destructive environmental monitoring.

Bangi and Juinio-Meñez [14] investigated the sea urchin *Tripneustes gratilla*, a major grazer, to assess its response to habitat changes near fish farms in Bolinao, Philippines. These researchers compared the feeding and reproductive traits of sea urchins in three seagrass beds located at different distances from the fish farms. Sea urchins closer to the farms exhibited smaller gut and feeding structures, lower consumption rates, and reduced gonadal indices, which were associated with reduced seagrass productivity and water movement. In contrast, the increased size of Aristotle's lantern observed at more distant stations was not attributed to food limitations. This study underscores the sensitivity of *T. gratilla* to environmental changes that may influence food quality variability.

Identifying species within an ecosystem is vital for ecological research and conservation efforts, and DNA barcoding can significantly speed up this process while complementing traditional methods. Guzzi et al. [15] employed a "Reverse Taxonomy" approach, in which DNA barcoding is followed by morphological analysis, to identify 70 echinoid and 22 crinoid specimens from two Antarctic regions: Terra Nova Bay (TNB, Ross Sea) and the Arctic Peninsula (Weddell Sea). This study identified 13 sea urchin species, including six new records for TNB and four crinoids, and corrected a previous misidentification of an echinoderm species. Notably, all identified crinoids were new records for TNB. This research sets a baseline for future biodiversity studies, especially within the TNB region, now part of the Ross Sea Marine Protected Area.

Goeting et al. [16] investigated the largely unexplored marine benthic diversity of the Palawan/North Borneo ecoregion, known for its high species richness. This study focused on benthic foraminifera from the Brunei shelf, identifying 99 species across 31 families and 56 genera from depths ranging from 10 to 200 m. Notably, 52 of these species were recorded for the first time in the region. Oxygen isotope analysis of selected species indicated cooler temperatures at greater depths, while carbon isotope data revealed species differences related to habitat preferences, food sources, and biomineralization. This study observed that species diversity increased with depth, suggesting greater disturbance in shallow waters and more pronounced specialization in deeper waters. Additionally, the results of this study indicate the presence of (at least) three biotopes on the Brunei shelf, each associated with different depth classes, thereby providing valuable insights into the regional diversity and distribution of foraminifera.

Previous research on *Corallina officinalis* (Plantae, Rhodophyta) has underscored its significant role in supporting high invertebrate biodiversity, attributed to the complex habitat structure it provides. Buršić et al. [17] examined seasonal variations in invertebrate assemblages at nine sites in the coastal region of southern Istria and the Brijuni National Park (Croatia, Adriatic Sea). These researchers recorded 29,711 invertebrates in winter, when algal growth is at its peak, and 22,292 in summer, when algal growth is minimal. Invertebrate abundance increased with algal biomass, with the highest density—586,000 individuals per square meter—observed in the Premantura area during the winter. The dominant invertebrate groups were amphipods, polychaetes, bivalves, and gastropods. This study deepened our understanding of *C. officinalis* turfs and confirmed the high invertebrate richness associated with these settlements.

In 2023, two exotic gastropod species, *Ocinebrellus inornatus* and *Rapana venosa* (Neogastropoda: Muricidae), were detected in Galician waters (Spain). Bañón et al. [18] reported new data on the occurrences of these species in this region, confirmed through morphological analysis and DNA barcoding. *O. inornatus* is now established in the Illa de Arousa (Ría de Arousa), while *R. venosa* was confirmed in this Ria, with evidence that its range extends beyond this area. These species probably arrived through imported shellfish, with this study emphasizing the need for a monitoring program to track the spread of exotic marine species.

In 2022, a baited camera was deployed for the first time in the Cosmonaut Sea, East Antarctica, capturing images at a depth of 694 m. Mou et al. [19] identified 31 species, including 23 invertebrates and 8 fish across eight phyla, from a collection of 2403 pictures and 40 videos, with the Antarctic jonasfish *Notolepis coatsi* being the most frequent fish species. This study documented ten vulnerable marine species and characterized the macrobenthic community as sessile suspension feeders, associated with fauna inhabiting muddy substrates interspersed with rocks. This research provides essential insights into macro- and megafauna communities and their habitats, establishing a baseline of Antarctic biodiversity that will support future ecosystem monitoring and conservation efforts in the Cosmonaut Sea.

In the final paper of this Special Issue, Hernández-Casas et al. [20] investigated the spatio-temporal variability of macroalgae communities in Xpicob and Villamar (Mexico) during three climatic seasons. This study identified 74 taxa from three classes: Phaeophyceae (3), Florideophyceae (36), and Ulvophyceae (35). Filamentous algae dominated the intertidal zone, while fleshy and calcareous algae were more prevalent in deeper waters. Twenty-eight species were found in both sites, with 46 taxa being site-specific: 13 in Xpicob and 33 in Villamar. Results indicated that species richness and distribution varied with environmental factors, with winter rains promoting algal growth in Xpicob and the dry season favoring Villamar. These findings underscore the considerable impact of local conditions on macroalgae communities and greatly enhance our understanding of these vital marine resources, which are valuable for marine management and conservation efforts.

In summary, this Special Issue compiles eight research articles, two communications, and one brief report, providing a comprehensive exploration of marine ecosystems ranging from shallow coastal waters to the depths of the ocean. These studies examine a diverse array of benthic habitats, including soft sediments, seagrass meadows, and rocky and artificial substrates, with research conducted across four continents—Antarctica, Asia, Europe, and North America—and within all major climate zones: polar, temperate, and tropical. The primary focus has been on macrofauna, examined at community and species levels, with some studies addressing megafauna, foraminifera, and macroalgae. These works employed a blend of traditional and remote sensing techniques for data collection, along with taxonomic, molecular, and biogeochemical methods for laboratory analysis. By utilizing a range of diversity and physiological indices, as well as advanced statistical techniques, the studies within this Special Issue have succeeded in describing and characterizing previously unexplored areas, identifying invasive species, monitoring pollution sources, and testing innovative substrates to enhance monitoring efforts. Collectively, this Special Issue makes a significant and inspiring contribution to our understanding of marine ecology and biogeography, offering valuable insights to support the conservation and management of marine benthos.

However, given the vastness of marine benthos, there is still much to explore and understand. Future benthic studies should aim to be more cost-effective and innovative in maximizing data utilization—critical steps toward achieving an ecosystem-based approach to the sustainable use of the marine environment. This will require a harmonious blend of traditional methods with cutting-edge techniques such as remote sensing, statistical modeling, and mapping. Additionally, integrating diverse types of data, including morphological, environmental, molecular, and isotopic information, will be key to unlocking a deeper understanding of these complex ecosystems [21–23].

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List of Contributions

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