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Editorial

Ecology of Marine Zooplankton

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1. Overview

Marine ecosystems, from coastal areas to open waters, teem with a multitude of heterotrophic and mixotrophic organisms collectively forming the zooplankton, the animal component of the plankton. Zooplankton is an extremely variegated group, with an outstanding phylogenetic, taxonomic and functional diversity [1], a biological richness that captivated even Charles Darwin during his voyage aboard the HMS Beagle, as described in [2]. Almost all phyla are represented in marine zooplankton, although crustaceans represent the dominant component [3].

Dimensionally speaking, the size of these organisms ranges between 2.0 µm (nanozooplaknton) and 20 m (megazooplankton) [4], covering an exceptionally wide gamut of size fractions. A typical distinction is made between holoplanktonic and meroplanktonic species, with the former spending their entire life cycle in a pelagic form and the latter spending only a transitory planktonic stage [5]. Dietary speaking, zooplankton as a whole includes bacterivores, herbivores, carnivores, omnivores, and detritivors, as well as parasitic forms [5]. From an ecological perspective, zooplanktonic organisms provide the linchpin between different trophic levels; they contribute to the biological carbon pump, regulate the biomass stock of other planktonic groups, affect ecosystem dynamics, are excellent beacons of climate change, and are crucial in providing ecosystem services, as recently reviewed in [6,7]. As such, improving our understanding of the ecological role of zooplankton implies improving our knowledge of the functioning of marine ecosystems as a whole [7].

The overarching goal of this Special Issue, themed "Ecology of Marine Zooplankton", is to present novel research on the biology and ecology of zooplanktonic organisms. The collection includes nine articles, one opinion paper, and one review. The subjects cover multiple themes, from host–parasite interactions to seasonal variability, over a wide range of scales—from the molecular to the population one scale—and systems investigated—from lagoons to hydrothermal vents. The result is a cross-cutting, strongly interdisciplinary volume that may attract the interest of researchers from different fields.

2. Contributions

In their paper, Litvinyuk et al. [8] perform a study to assess the non-consumptive mortality rate of zooplanktonic organisms, mainly copepods, and the decomposition and sedimentation rates of carcasses in Sevastopol Bay. Their work reveals a high variability in these parameters, suggesting a reduced sedimentation rate of copepod carcasses in turbulent conditions, and a comparable rate of sedimentation and microbial decomposition, confirming the important role of copepod carcasses in coastal waters.

Köster and Paffenhöfer [9] investigate the role of the predation by the doliolid *Dolioletta gegenbauri* on the abundance of the small neritic copepod *Paracalanus quasimodo*. Their laboratory experiments show that *D. gegenbauri* can ingest *P. quasimodo* eggs at a rate similar to that with which the doliodid preys upon phytoplankton cells. Conversely, the predation

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on copepod nauplii is significantly lower, likely due to the ability of motile nauplii to detect *D. gegenbauri* feeding currents. Based on these outcomes, the authors speculate about the effect of doliolid predation on copepod community composition.

The effects of several coccolithophore species, differing in cell size, and carbon and calcite content, on copepod grazing (ingestion and egestion rates) are investigated in the copepods *Temora longicornis* and *Acartia clausi* by Toullec et al. [10]. The authors find that the cellular volume and calcite content of the species strongly affect the copepod foraging capability and production of faecal pellets. In particular, contrary to the optimal foraging theory, copepod ingestion rates increase exponentially with food availability, likely due to food quality (calcite content). A decoupling between ingestion and egestion rates is also associated with a possible obstruction of the copepod gut related to calcite itself. Their study has important implications for the production and sedimentary flux of copepod faecal pellets into deeper waters.

Martinelli Filho et al. [11] report for the second time the infection of paracalanid copepods by the alveolate parasite *Ellobiopsis chattoni* Caullery, 1910 in South Atlantic, in subtropical coastal areas in the south-east of Brazil. *E. chattoni* is mostly found attached to the cephalosome appendages of *Paracalanus* spp. And *Parvolacanus crossirostris*, and is rarely found in the copepod taxa (59) identified in the same samples. However, parasitized copepods are mainly females rather than males and juveniles, and the highest percentage of infected copepods is observed in the winter and summer seasons of different years. This study shows that this infection by the alveolate has a negative impact on the growth and fitness of future copepod populations.

Zooplankton communities are investigated in studies by Gubanova et al. [12] and Chaigneau et al. [13], respectively, in response to climate change and seasonal variations in the Black Sea and a lagoon in West Africa, areas where little is known about the zooplankton diversity. Gubanova et al. [12] assess the response of the mesozooplankton community in Sevastopol Bay, a semi-enclosed estuarine-type bay, to the most persistent and intense marine heat wave recorded in the Black Sea (summer 2010). Using long-term routine observations (2003–2014), the study reports seasonal variations in zooplankton composition, abundance, and structure; warm water and non-native species (e.g., *Oithona davisae* and *Acartia tonsa*) showed the maximum seasonal density, suggesting their greater flexibility to adapt in response to environmental changes. *O. davisae* is suggested as an indicator of the environmental conditions associated with the warming of the Black Sea and the whole Mediterranean basin.

Chaigneau et al. [13] investigate zooplankton diversity and abundance in the Nokoué Lagoon in southern Benin (West Africa). In response to the high seasonal variations of salinity, the authors report differences in the zooplanktonic assemblages: during high water periods (fresh water), zooplanktonic diversity and abundances are quite high, mostly dominated by rotifers, compared with brackish water periods, when diversity is minimal and abundance decreases slightly. However, in some areas of the lagoon, changes in zooplankton abundances are independent of salinity levels, suggesting other factors (e.g., riverine inputs, fish traps) as potential drivers.

The spatial and temporal variability of plankton depends on environmental parameters. In their contribution, Prakash et al. [14] investigate the role of salinity gradients on bacterioplankton, phytoplankton, and zooplankton abundance and diversity in the highly productive Hooghly River Estuary in West Bengal, India. They find zooplankton distribution strongly affected by water circulation, bacteria, and Chl *a* content, with higher abundances of rotifers and cladocerans in lower salinity stations and copepod dominance in downstream stations with higher salinity. Their results confirm the importance of foraging strategies (bacterivory, herbivory, and omnivory) in shaping plankton communities, which could have implications for the production of commercially valuable fish and shrimp species in the estuary.

The structure of the mesozooplankton community in relation to water mass conditions in the Southeast China Sea is also studied by Wang et al. [15]. The authors find significant

changes in the mesozooplankton community structure and copepod assemblages in the upwelling cold dome region, formed by the Kuroshio Current intrusion in the Southeast China Sea during the southwest monsoon. Copepod species indicators of low temperature and nutrient-rich water masses characterize the cold dome with respect to the area sampled the following season.

Hydrothermal vents represent perfect natural laboratories to study the ocean biota in future climate scenarios. In their opinion paper, Dahms et al. [16] inquire into the appropriateness of these systems for zooplankton studies, reviewing the available literature on the topic. The authors conclude that shallow water vents can offer a unique possibility to understand the possible effects of global change on the resident and allochthonous zooplankton assemblage, and propose leading questions to be addressed in future studies.

The iron metabolism in copepods is investigated in Roncalli et al. [17]. Attention is focused on identifying transcripts encoding ferritin, a highly conserved and ubiquitous multimeric iron storage protein required for the maintenance of iron homeostasis. Using an in silico workflow on 27 publicly available copepod transcriptomes, the authors describe the diversity of these proteins and infer their functions using gene expression data in three target species exposed to stressors and across development. Results point to species-specific differences suggesting ferritins as potential copepod biomarkers of multiple processes, such as development, stress response, and iron storage.

An updated review of the distribution of the non-indigenous calanoid copepod *Pseudodiaptomus marinus* in European and neighboring waters is given in Uttieri et al. [18]. Starting from a previous survey, the authors summarize published literature (from fall 2019 to date) and present original evidence showing the continuous expansion of this species. The data presented provide a real-time snapshot of the occurrence of *P. marinus* and are used to hypothesize future distribution scenarios.

3. Conclusions

The contributions included in this Special Issue cast fresh light on the complexity of zooplankton ecology, and further our current knowledge on the mechanisms regulating processes and dynamics taking place at different spatial and temporal scales. Such comprehension, however, is still far from being exhaustive: much has been undertaken over the last decades, but more is yet to come. As guest editors, we gratefully acknowledge the dedication of all contributing authors, and the time devoted by the reviewers to assess the quality and merit of the submitted works. We are confident that the reference scientific community will be deeply inspired by the papers included in this topical collection, which will surely stimulate new and productive research ideas.

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