ZOOPLANKTON ECOLOGY

Editors

M. Alexandra Teodósio

Ana B. Barbosa

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M. Alexandra Teodósio

and

Ana B. Barbosa

Centre of Marine Science (CCMAR)
University of Algarve, Campus de Gambelas
Faro, Portugal

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Preface

Zooplankton comprise a vast diversity of organisms, from unicellular phagotrophic protists to metazoans, including both non-gelatinous and gelatinous invertebrates and vertebrate eggs and larval stages. Zooplankton inhabit all different types of aquatic systems, which cover ca. 72% of the Earth's surface. Zooplankton play a pivotal role in ecosystem functioning, representing a link between phytoplankton and higher trophic levels, including living aquatic resources. Zooplankton also play a fundamental role in global biogeochemical cycles and ocean carbon pump, acting as connectors between ocean surface processes and communities, and the deep benthic ocean realm. Considering the current focus on environmental change and related anthropogenic stressors, it is more crucial than ever to get a comprehensive knowledge on the environmental drivers of zooplankton, in order to able to predict their responses to natural and anthropogenically-induced environmental changes. According to the Intergovernmental Panel on Climate Change (IPCC) projections, by 2100, average temperature will increase by 0.6–2.0ºC and pH will decrease by 0.1–0.4 units in the oceans' upper surface layer. Zooplankton is and will face dramatic changes, including ocean warming, acidification, deoxygenation, and plastification. Global change will likely continue to intensify as the world population continues to grow exponentially. Urban, agricultural, and industrial development will also continue to alter biogeochemical cycles, and possibly increase the frequency of extreme climatic events. Moreover, anthropogenically-mediated introduction of non-native species, namely zooplanktonic life phases (ballast water), facilitated by the absence of physical natural barriers in ocean, may further disrupt food webs and impact commercial fisheries.

Au.: Is what?

The wide diversity of zooplanktonic representatives, illustrated in the book front cover, is associated with multiple organism sizes, functional traits, specific ecological functions, environmental drivers, control modes, environmental stressors and varying methodological approaches, from sampling to quantification. This great complexity has been frequently scattered into textbooks and articles tailored to different audiences. As example, freshwater and marine zooplankton studies are usually separated, as well as metazoans from phagotrophic protists, bottom-up controls from top-down controls, and even fish larvae are frequently perceived as a zooplankton singularity, at the interface with fisheries biology. Although these dichotomies are understandable, they have fragmented this sub-field of marine ecology.

In this context, this book aims to capture key areas of research on zooplankton ecology, using an integrative approach covering both marine and freshwater zooplankton, including phagotrophic protists and metazoans, and their bottom-up and top-down controls, spatial-temporal distribution patterns and emergent methodological approaches. Overall, the book chapters represent a wide array of studies based on the use of multiple approaches including comprehensive synthesis, observational studies, undertaken at different spatial and temporal scales, manipulative studies, and even sediment analysis, a vibrant imprint of benthic-pelagic coupling and ecosystem connectivity. Omics approaches, that have enabled us to assess the biodiversity at an unparalleled scale, are integrated in several chapters. Most chapters also address the specific impacts of anticipated environmental changes and stressors (e.g., warming, ocean acidification, eutrophication), and conclude with the current challenges, opportunities and avenues for continued study.

The book is divided into 12 chapters, integrated in three major sections. The first section addresses zooplanktonic organisms, processes and control, the second section is devoted to zooplankton spatial and temporal distribution patterns and trophic dynamics, and the final section is dedicated to innovative tools and approaches for studying zooplankton ecology.

In the first book section, Chapter 1 provides a comprehensive analysis of zooplankton functional traits. This chapter includes information for both fresh-water and marine zooplankton representatives, and addresses multiple traits (morphological, behavioral, stoichiometric and physiological, life history traits), and highlights lesser studied traits, taxa and habitats. Chapter 2 explores two main interactions between phytoplankton and zooplankton, consumptive and non-consumptive. This chapter emphasizes how chemical communication shapes the interactions between dominant primary producers and consumers, and how zooplankton can act as a bottom-up and top-down control on phytoplankton. Chapter 3 provides a thorough historical overview of the hypothesis behind fish recruitment, considering the dynamic controls of ocean physical, chemical and biological processes on fish larvae. This chapter also explores a specific multidimensional functional trait of fish larvae, behavior, as an integrative modulator of fish recruitment, thus providing a linkage with fisheries biology. Chapter 4 revises the effects of a current stressor, ocean acidification, on zooplankton assemblages, and explores a specific case study over shallow-water CO_2 submarine vents (NE Atlantic). This chapter used CO_2 vents as a natural surrogate for anticipated ocean acidification for analysis of its effects on copepod individual fitness and zooplankton structure.

In the second book section, Chapter 5 examines biodiversity patterns of tintinnid ciliates combining complementary approaches, conventional morphology-based microscopy and DNA sequencing, thus unravelling species crypticity and polymorphism. This chapter explores the distribution patterns of phylogenetic diversity of tintinnids, and underlying factors (salinity, depth and latitude), at global, regional and local scales. Chapter 6 explores the global distribution patterns of other groups of phagotrophic protists, foraminifers and polycystine radiolarians, and hypothesis that may explain their dissimilarities. The use of sediment samples in tandem and some of the proposed hypothesis (isothermal submersion) clearly reflect the relevance of connectivity between pelagic and benthic sub-systems. Chapter 7 provides a comparative analysis of zooplankton distribution and trophic dynamics over four highly productive coastal upwelling systems (California, Humboldt, Canary and Benguela Current systems). This chapter also discusses the relevance of zooplankton behavioral strategies for retention and dispersion during upwelling-relaxation events, at the small- to mesoscale levels. Chapter 8 evaluates intra- and interannual variability patterns of planktonic assemblages in the Baltic Sea, with emphasis on metazooplankton annual succession, associated functional traits, annual routines and life histories, trophic dynamics, and phenology. The use of this specific case study, brackish water ecosystem, creates additional opportunities for exploring zooplankton temporal dynamics across salinity and latitudinal gradients. Chapter 9 guides the readers over a set of simple visualization techniques for evaluating and comparing zooplankton intra- and interannual variability patterns and trends across time and space, along with underlying environmental determinants. This chapter explores zooplankton time series, with different methods and lengths, and represents a contribution at the interface between zooplankton distribution patterns and methodological approaches.

In the third book section, Chapter 10 introduces the ecology of the highly diverse gelatinous zooplankton and explores new technological approaches for *in situ* jellyfish monitoring, including acoustic, optical and environmental DNA sensors, installed onto robotic platforms (remotely operated vehicles, autonomous underwater vehicles). This chapter specifically emphasizes the relevance of citizen science-based programs, as a complement to current monitoring efforts, which globally enhance sampling resolution and promote an engaged ocean literate society. Chapter 11 reviews the main steps in metabarcoding studies of zooplankton, including sampling, DNA extraction, amplification and sequencing, and data analysis. This chapter also provides recommendations for minimizing

methodological biases, and obtaining ecologically relevant information (barcode choice, reference database, sequence processing and clustering and taxonomic assignment). Chapter 12 provides an overview on how omics techniques (metagenomics, metatranscriptomics, metaproteogenomics) are currently fostering the research in zooplankton, contributing to characterize their spatial and temporal distribution patterns, life cycles and ecological functions.

After this brief overview of the book chapters, finally, and above all, we gratefully acknowledge all authors for their effort, talent and insightful contributions. Overall, this book aims at providing students and researchers an advanced integrative overview of zooplankton ecology. This multi-authored book is not a conventional textbook. Yet, we sincerely hope our book proves useful for our past, current and future students, who have been a constant source of inspiration and the prime motivation to accept the challenge of editing this book. Enjoy …

Faro, February 7, 2020

M. Alexandra Teodósio

Ana B. Barbosa

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