MICROZOOPLANKTON, KEY ORGANISMS IN THE PELAGIC FOOD WEB

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Summary

Microzooplankton are a group of planktonic predators (both unicellular and metazoan) between 20 and 200 µm size that occupy a key position in marine food webs. Important contributors to the group are flagellates, dinoflagellates, ciliates, acantharids, radiolarians, foraminiferans, copepod nauplii, rotiferans and meroplanktonic larvae. Microzooplankton are the main grazers in most marine ecosystems on Earth, from ultra-oligotrophic to upwellings, where they outcompete copepods and other larger zooplankters.

The grazing pressure of microzooplankton in these contrasting ecosystems, even if variable among studies, is quite constant on a general basis (ca. 60-75% of the phytoplanktonic primary production is consumed daily). Microzooplankton are also important contributors to the diet of mesozooplankton (copepods), and have key roles in marine ecosystems as nutrient recyclers, and CO_2 producers. This article also briefly describes the effects that human and climate forcing may have on microzooplankton, and presents some predictions on the fate of microzooplankton populations under different global change scenarios.

1. Introduction

Strictly speaking the term microzooplankton represents a group of heterotrophic and mixotrophic organisms, whose size is between 20 and 200 µm. However, this definition is now used in a laxer way, including all phagotrophic protists and metazoans smaller than 200 µm. This new view of the group encompasses several taxa of organisms as different as a small mixotrophic unicellular flagellate and a copepod nauplius. Obviously, this adds complexity to the understanding of the function of the group in pelagic food webs. However, all of this sort of life forms still holds something in common, their role as predators. From the phagotrophy of particles by invaginating vacuoles, to the complexity of prey detection and capture by nauplii mouth appendages, microzooplankton serve their function as predators. Their prey are also diverse and characteristic of each microzooplanktonic group considered, meaning their impacts will be highly specific.

Traditionally, microzooplankton was relegated to a secondary place when describing the dynamics of marine ecosystems, especially those of productive waters. However, present research has revealed this group as one of the most important, together with phytoplankton and bacteria, in the biogeochemical cycles of the different organic and inorganic compounds. Microzooplankton circulates most of the primary production that is not lost by sedimentation or advection. Unfortunately, their key role in oceans and seas is not still reflected in many food web conceptual and predictive models. Therefore, this article will try to present a summary of the present research on the group, defining their function in the different marine ecosystems, and providing some budget calculations to emphasize, in general terms, the importance of this group in relation to other components of marine food webs. Because of their ecological relevance this article will mostly deal with the role of microzooplankton as predators of primary producers. Additionally, we will try to position microzooplankton in the biogeochemical cycles as CO_2 producers and nutrient and organic matter recyclers. Microzooplankton serve also as food of many other planktonic organisms; therefore the function of these key organisms in the planktonic realm would be incomplete without a few words on the present knowledge on the subject. Finally, we will discuss some perspectives about the evolution of the group in the face of anthropogenic forcing and different climate change scenarios.

2. Main microzooplankton groups

A first, and obvious, classification of microzooplankton is that of dividing the group into protists and metazoans. Microzooplankton protists are represented by both mixotrophic and strict heterotrophic organisms, including flagellates, dinoflagellates, ciliates, acantharids, radiolarians, foraminiferans, etc. The concept of animal and vegetal becomes tricky when relating to unicellular organisms. Here we have decided to use the word protists (generally including animals and organisms showing phototrophic pigments) instead of protozoans (specific to animals) for consistency. We should be aware however, that many unicellular organisms, even if conducting photosynthesis, can be voracious predators.

Retuning to our classification, among metazoans we found small worms, such as rotifers, meroplankton (polychaete larvae, echinoderm larvae, etc) and larvae of holoplanktonic organisms (copepod nauplii, copepodites, etc.).

Flagellates usually fall in the size-range of nanoplankton (2 to 20 µm). However, some large forms may be considered microzooplankton. They can be heterotrophic and mixotrophic. They are active consumers of bacteria, but larger species can engulf smaller flagellates. It is accepted their role in the food webs is mostly focused on the control of bacterial populations, including autotrophic prokaryotes, the main primary producers in the most oligotrophic regions of the oceans.

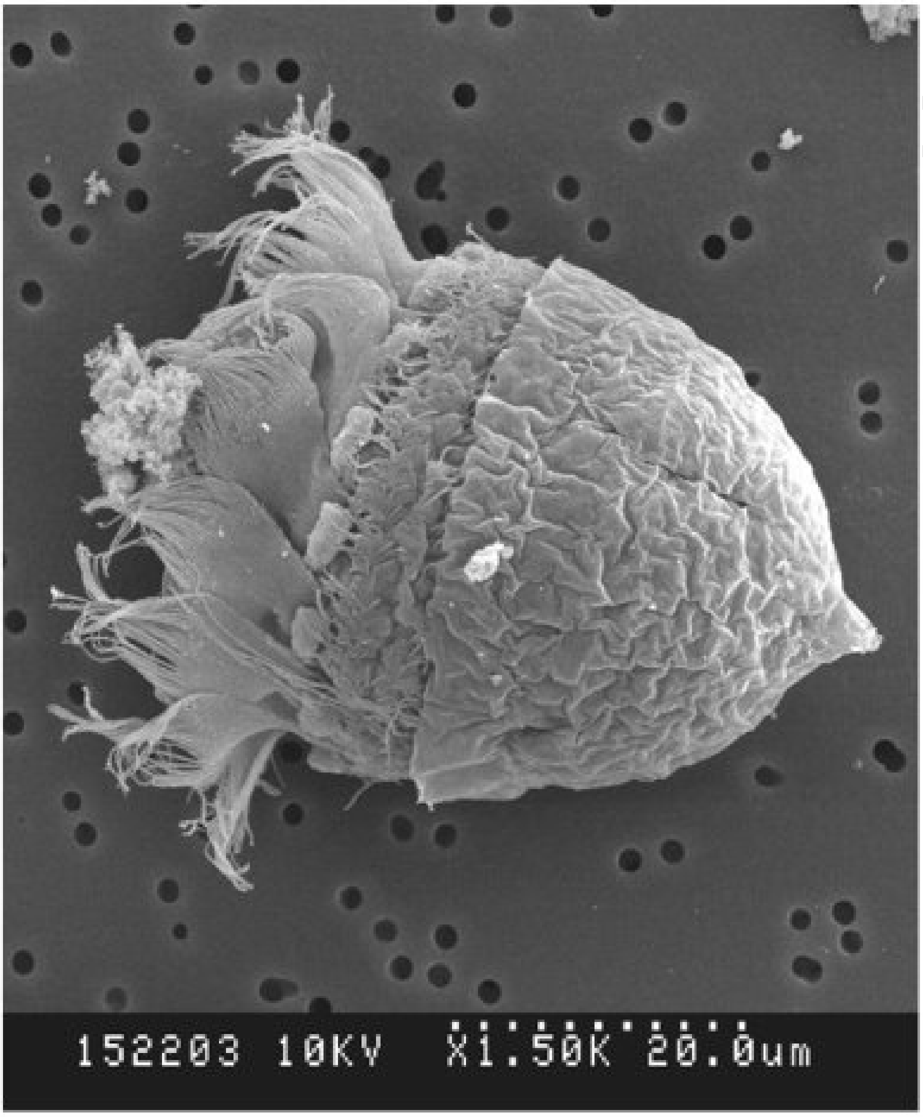

Figure 1. Tintinnid ciliate from NW Mediterranean coastal waters. This ciliate was isolated from a natural sample during a toxic dinoflagellate bloom. The picture was taken using scanning electron microscopy.

Ciliate protozoans (Figure 1) are recognized as the main group of microzooplankton, because their abundance and trophic role in the food web. However, present research is questioning this preponderance in the planktonic ecosystem, highlighting other groups such as the dinoflagellates. Both groups of protists have adopted similar trophic strategies (including heterotrophy, and mixotrophy), although the later relay more heavily on phototrophy. It is when using this light and nutrient dependent trophic feeding strategy when dinoflagellates can reach "bloom" densities (red tides). Ciliates usually feed on smaller prey (from bacteria to small algae, with a relationship between predator and optimal prey size around 1:8), although examples of predators of large prey are also found. They capture their prey by generating feeding currents with their cilia, attracting by this way the prey to the oral opening. Dinoflagellates capture larger prey (even larger than their own size) by 3 different raptorial mechanisms: pallium feeding, tube feeding, and direct engulfment. They can be active predators during diatom blooms.

Acantharids, radiolarians and foraminiferans are common components of microzooplankton in oceans and seas. They are found at different depths in the water column, from surface to 1000 m depth. They can feed on a variety of prey, including bacteria, other protists and algae, and even small metazoan zooplankton. Furthermore, many species also retain symbiotic algae (providing a primary source of nutrition).

Rotifers and meroplankton (Figure 2) are typical components of coastal communities. Rotifers are small metazoans characterized by a ciliated corona around the mouth (usually in the form of two lobes surrounded by beating cilia), which give a vivid impression of rapidly rotating wheels. The current created by the corona helps to propel the rotifer and also brings food particles to the mouth. Their role as predators is mostly evident during dense phytoplankton bloom periods, where they can become the dominant grazers.

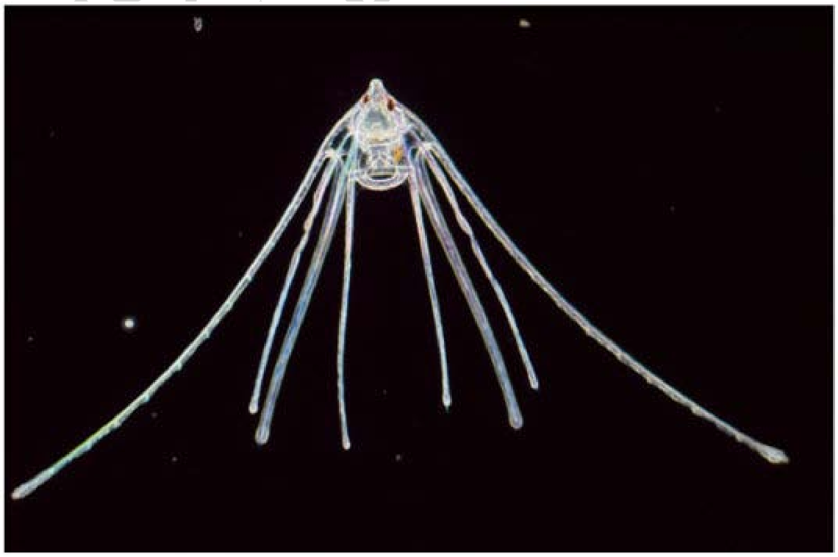

Figure 2. Larval stage of a sea urchin (Ophiura). The picture was taken using phase contrast microscopy.

The term meroplankton encompasses a great variety of larval forms of benthic organisms (sea urchins, sea stars, worms, crustaceans, etc). Their role in the ecosystem is diverse and highly seasonal and episodic (especially in those species that present synchronic reproduction).

Finally, in this review of the most common microzooplankters we cannot forget nauplii (Figure 3). Nauplii are the larval form of copepods and other pelagic and benthic crustaceans. They are the most abundant metazoans in the oceans, and probably on Earth. Their prey detection and capture mechanisms are similar to that of adult copepods, although more rudimentary, given the simplicity of their feeding appendages. They usually prey upon moving cells of medium size, and their role in the ecosystem is similar to that of copepods, but scaled to their size and biomass.

Figure 3. Nauplius of the copepod *Acartia grani*. The picture was taken using phase contrast microscopy.

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Biographical Sketches

Albert Calbet was born in Barcelona, Spain, in December 1968. He has aDegree in Biology from the University of Barcelona (1992), and Ph.D. in Marine Sciences at the Institut de Ciències del Mar (CSIC) in 1997. He was awarded a postdoctoral fellowship from the Ministry of Education and Culture (Spain) to work at the University of Hawaii (USA) from march 1997 to March 1999. In May 1999 he was contracted by the University of Hawaii as postdoctoral scientist under the HOT (Hawaiian Ocean Time-series, JGOFS) program. In September 1999 he returned to Barcelona to work at the Institut de Ciències del Mar (CSIC) under a research contract by the Ministry of Education and Culture, where he now holds a tenured position. He is professor of the Doctorate in Marine Sciences of the University of Barcelona and the Polytechnic University, and of the Doctorate in Oceanography of the University of Las Palmas de Gran Canaria-CSIC.

He is advisor and reviewer of several national and international agencies, and journals, currently being a member of the editorial board of the Journal of Plankton Research. He has participated in 19 national and international research projects and 22 scientific cruises. His work has led to 50 presentations to international meetings or workshops, and also nearly 50 peer reviewed papers published in first rate international journals on marine ecology. His research topics include the ecology of marine zooplankton, planktonic food webs dynamics, and the interaction between physical characteristics and biological phenomena, among others.

Miquel Alcaraz was born in Barcelona, Spain, in July 1945. He has a Degree in Biology from the University of Barcelona (1969). His Ph.D. Thesis on Biology obtained the Excellence Doctorate Award of the University of Barcelona (1977). Research Professor at the Institut de Ciències del Mar of Barcelona (CSIC) since 1987, he is member of the Doctorate Commission in Marine Sciences of the University of Barcelona and the Polytechnic University, and professor of the Doctorate in Oceanography of the University of Las Palmas de Gran Canaria-CSIC. Currently participating in evaluation panels for national and international research projects, and also part of the editorial board of several international scientific journals related with marine sciences.

During the last 10 years he has participated in 10 national and international research projects and a similar number of oceanographic cruises, in some of them as coordinator, and has assisted in 18 international congresses and symposia, in some of them by invitation, or as chairman of sessions. Since 1996 he has published about 30 scientific papers and book chapters in first-rate international journals. His research expertise includes plankton ecology, zooplankton systematics and community structure, phyto-zooplankton coupling, zooplankton physiology, control of rate-processes in micro- and mesozooplankton, and interaction between physical variability and biological phenomena at multiscale.