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How does mesh-size selection reshape the description of zooplankton community structure in coastal lakes?

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ABSTRACT

To provide evidence of the inadequacy of using conventional sampling methods to study mesozooplankton community structure in confined environments, samples from a Mediterranean meromictic coastal lake were taken using 80-μm and 200-μm mesh nets towed at three different depths (0–18 m). Mesh size significantly affected the description of the community structure of the collected zooplankton. The 80-μm-mesh catch revealed for the first time in such an environment the overwhelming abundance of the copepod species *Oithona brevicornis*, as two orders of magnitude greater than recorded for the 200-μm-mesh catch. The other dominant species were *Paracartia latisetosa* and *Pseudodiaptomus marinus*, which were more efficiently sampled with the 200-μm mesh. These showed a summer abundance peak for *P. latisetosa* near the surface layer, and for *P. marinus* in the deepest stratum, close to the anoxic layer. Copepod nauplii and bivalve larvae were more efficiently caught with the 80-μm-mesh, and accounted for most of the zooplankton in winter, and showed the highest loss percentage of abundance between the two mesh-size catches. The differences in the assemblages reflect different diversity patterns, with peaks in summer and winter for the communities collected with the 80-μm-mesh and 200-μm-mesh, respectively. These findings imply the need for the development of a commonly used sampling method with paired nets, to correctly take into account both the large and small fractions of the mesozooplankton in the study of closed and semi-enclosed coastal environments, and to obtain data that can be better compared across studies.

1. Introduction

The efficiency of a particular zooplankton sampling tool is generally related to the composition, structure and density of the assemblage to be sampled and to the environmental features. Consequently, many methods and tools have been developed and applied to zooplankton studies (e.g., Kršinić and Lučić, 1994; Gallienne and Robins, 2001; Stehle et al., 2007; Gutkowska et al., 2012). Despite these studies, there are still no universal instruments or mesh size that correctly sample all zooplankton groups, to include the developmental stages in all areas, under different productivity conditions, and for different seasonal periods and vertical zonation patterns. This is because zooplankton size structure within the same environment changes over space and time. Among the many factors that can affect sampling efficiency, the mesh selection is undoubtedly the major source of error. The WP-2 plankton net (200-μm mesh size) (UNESCO, 1968; Sameoto et al., 2000) is still the most commonly used for marine zooplankton sampling. Indeed, several dominant components of marine mesozooplankton, such as many *Oithona*, *Oncaea* and *Paracalanus* spp., and some *Clausocalanus* spp. pass through coarser nets (>200 μm), which would thus provide incomplete descriptions of the zooplankton community structure in pelagic and coastal ecosystems. In contrast, a reduction in the mesh size has a negative effect on the rate of plankton retrieval through the filtration process. This has frequently led to underestimating the abundance of the smaller copepod species and the early developmental stages, which can be numerically dominant in pelagic communities and in confined or semi-enclosed coastal areas (e.g., Paffenhöfer, 1993; Hwang et al., 2007; Pitois et al., 2009; Tseng et al., 2011; Rakhesh et al., 2013; Miloslavić et al., 2014). Antacli et al. (2010) provided the first report of three representative copepod species collected for the Patagonian Shelf, where they sampled with paired nets of 66-μm mesh and 150-μm mesh, which indicated the benefits of using 66-μm plankton nets to estimate the abundance of these three copepod populations. Overall, 200-μm-mesh nets capture

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about 7% of the mesozooplankton community in terms of numbers (Gallienne and Robins, 2001). Additionally, some studies have reported not only an underestimation of zooplankton abundance with mesh sizes >100 μm, but also unreasonable estimates of some smaller zooplankton organisms, such as rotifers (Chick et al., 2010). Rodriguez et al. (2013) demonstrated how a 55-μm-mesh net is more efficient than a 100-μm-mesh net for the collection of rotifers in a freshwater river. Belmonte et al. (2013) demonstrated in detail how the use of a double mesh size is necessary to correctly compare open sea communities with the confined ones in the Taranto Sea system.

Therefore, a better understanding of the roles of mesozooplankton and copepods in aquatic ecosystems will only be possible when suitable and comparable sampling methodologies are used globally. Despite this increasing evidence, a commonly standardized sampling strategy that correctly takes into account both the large and the small fractions of the mesozooplankton in studies of closed and semi-enclosed coastal environments has not yet been developed. The use of such a method is now more urgent, because of even greater increases in anthropogenic activities, such as eutrophication of the coastal areas, which might result in the replacement of large copepods with smaller ones (Uye, 1994; Turner, 2004). In addition, the highest variability of conditions with time in confined environments allows the establishment of life cycles shorter than those admitted in more stable pelagic marine waters (Belmonte et al., 2013).

The location for the present study, Lake Faro, has been the subject of previous studies that were exclusively based on daytime catches, and identified *Acartia margalefi* Alcaraz, 1976 and *Paracartia latisetosa* (Kritchagin, 1873) as the key species of this ecosystem (Crisafi et al., 1973; Zagami and Guglielmo, 1995). A recent study based on daytime and night-time sampling in the same environment highlighted the gradual decrease, and almost disappearance, of *Oithona nana* Giesbrecht, 1893, with its progressive replacement by *Oithona brevicornis* Giesbrecht, 1892 (Zagami and Brugnano, 2013). To obtain more reliable estimates of the smaller copepods, such as those of the genus *Oithona*, which were likely to have been underestimated in this recent study, Zagami and Brugnano (2013) emphasized the need for further and more targeted sampling using finer mesh nets, recognizing the importance of such smaller copepods as the largest part of all of the zooplankton communities around the world (Gallienne and Robins, 2001; Zervoudaki et al., 2007; Antacli et al., 2010), as well as in this Lake Faro ecosystem. Most of the studies on this topic concern the marine systems, little is known about the coastal lakes.

The objective of the present study was to show that a different sampling method that uses both 80-μm-mesh and 200-μm-mesh nets can fully capture the variability in the zooplankton community structure over space and time, according to mesh size and sampling depth. With this demonstration of the inadequacy of a single-sized plankton mesh net to represent the whole mesozooplankton assemblage, we raise the question of the necessity for the use of paired mesh nets of different sizes in studies on both the large and small fractions of mesozooplankton in marine coastal environments.

2. Materials and methods

2.1. Study area

Lake Faro is a coastal ecosystem located in the north-eastern tip of Sicily that has a surface area of 263,600 m^2 and a maximum depth of 29 m (Fig. 1a). It has typical features of a meromictic basin; i.e., an oxic epilimnion (from the surface to 10–12 m in depth) and an anoxic hypolimnion (from 15 m to the bottom), which are characterized by large fluctuations in their physico-chemical parameters. This can be seen especially for the temperature (10–28 °C), salinity (34–37) and dissolved oxygen (absent near the bottom in the central area, to 8.3 mg L^{-1} at the surface along the shore). These layers are separated by the metalimnion, within which strong blooms of anoxygenic phototrophic bacteria result in the periodic development of a red water layer (Genovese, 1963; Truper and Genovese, 1968). The physical and chemical stratification is particularly sharp in summer, when anoxia typically extends up to the lower mixolimnion, and conspicuous blooms of photolithotrophic sulphur bacteria develop. The main component of these blooms has been identified as *Chlorobium phaeovibrioides* (Sorokin and Donato, 1975), which is a well-characterized member of the Chlorobiaceae that has adapted to low light intensities. Lake Faro is connected via a shallow channel to the Straits of Messina, which separate the island of Sicily from the Italian peninsula (Fig. 1). Another channel (known as the 'English channel'), which is silted up most of the time, is artificially opened for few days during the hottest summer period (June–August), to establish communication with the Tyrrhenian Sea, thus allowing water circulation into the lake.

2.2. Sampling methods

Zooplankton samples were taken every month from June 2009 to September 2010, along a central north-south transect of 30 m–75 m in length, which depended on season and sampling depth (Fig. 1a). A total of 96 samples were taken using nets of two different mesh sizes: 48 samples using an Apstein closing net (80-μm mesh size, 100-cm long, 40-cm mouth diameter) and 48 samples using a WP2 closing net (200-μm mesh size, 260-cm long, 57-cm mouth diameter). A digital flow meter (Hydro-Bios Kiel) was mounted at the mouth of each net, to calculate the water volume that was filtered. An average of 2.5 ± 0.5 and 12.5 ± 2.5 m^3 water volume was filtered during each catches for the 80 and 200-μm mesh size nets, respectively. This make a ratio filtering area/mouth area (adjusted to porosity) of about 11:1 and 6:1 for Apstein and WP2, respectively (Hernroth, 1987; Keen, 2013). Each tow was carried out horizontally at three different depths: Q1 (12–18 m), Q2 (8–11 m) and Q3 (surface to 8 m). At the end of the collection of each sample in each sampling layer, the nets were closed by dropping a messenger from on board. To maintain the nets at the correct depths, a 7-kg counterweight was mounted under the net-closing mechanism, together with a multiparameter CTD probe (YSI 6600V2), which measured the environmental parameters (i.e., temperature, salinity, dissolved oxygen, chlorophyll *a*) during the sampling (Fig. 1b).

The zooplankton samples were fixed in 4% sodium tetraborate buffered formalin and ambient water solution. The zooplankton were counted under a stereoscopic microscope in sub-samples that represented 1/100 to 1/25 of each of the entire samples, depending on their abundance in each sample. The whole samples were analysed for rare species. Adult copepods were identified to the species level (except for some harpacticoids, cyclopoids and poecilostomatoids), while the copepodite stages were identified to genus level. Specimens belonging to other zooplankton groups were classified to higher taxonomic levels. The abundances are expressed as individuals per cubic metre (ind m^{-3}).

2.3. Data processing

To evaluate the spatial and temporal patterns, the abundances were analysed using cluster analysis, based on the Bray–Curtis similarity matrix of the square-root-transformed abundance data, using the PRIMER Beta 6 software (Clarke and Warwick, 2004).