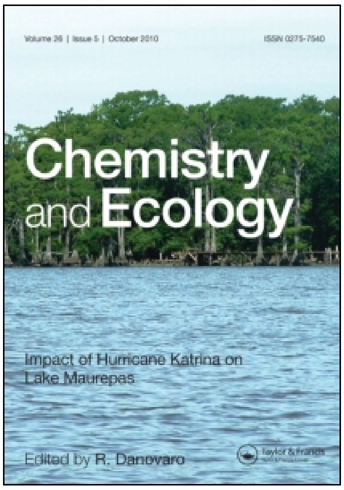

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Distribution, biomass and ecology of meso-zooplankton in the Northern Adriatic Sea

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DISTRIBUTION, BIOMASS AND ECOLOGY OF MESO-ZOOPLANKTON IN THE NORTHERN ADRIATIC SEA

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Two oceanographic cruises were carried out in the northern Adriatic Sea, from June, 1996 to February, 1997. Samples were collected using a BIONESS electronic multinet (204 samples on 54 stations) along inshore-offshore sections. Zooplankton abundance and biomass were estimated in relation to the variability of temperature, salinity and fluorescence. Spatial and vertical distribution patterns of the most important zooplankton groups were studied. During June, in the northern area, abundance and biomass of 2787 ± 1735 ind m^{-3} and 29.3 ± 26.7 mg m^{-3}, respectively, were reported. The zooplankton community was constituted essentially by copepods and cladocerans. In the southern area, instead, an abundance of 4698 ± 5978 ind m^{-3} and a dry weight of 25.4 ± 15.3 mg m^{-3} were observed, with a reverse dominance ratio between these groups. In February, in the northern area the zooplankton community (1380 ± 595 ind m^{-3} and 19.6 ± 9.9 mg m^{-3}) was mainly constituted by copepods, larvae of invertebrates, appendicularians and cladocerans; in the southern area zooplankton average abundance was 969 ± 493 ind m^{-3} and 9.9 ± 3.2 mg m^{-3} being copepods, cladocerans, appendicularians and larvae of invertebrates. The zooplankton spatial distribution, in this period, did not show the classic inshore-offshore gradient. Spatial distribution and biomass values of zooplankton, in the northern Adriatic Sea, were strongly influenced by hydrological characteristics, allowed up to formulate a preliminary model about distribution, along the water column, of the different associations of species assemblages with regard to different water masses in the neritic system.

Keywords: Mesozooplankton; distribution; ecology; Adriatic Sea

INTRODUCTION

Adriatic zooplankton has been studied since the first half of the last century (Claus, 1881; Car, 1890; Graeffe, 1900; Steuer, 1902a, 1902b, 1910a, 1910b).

Morphological, hydrological and hydrodynamic particular features of the northern Adriatic influence meso-zooplankton abundance and distribution. It is well known, that this basin is characterized by high zooplankton biomasses (Benovic *et al.*, 1984) which decrease along the North-South gradient. Meso-zooplankton presents, on the contrary, a low diversity, in the northern neritic zone, increasing towards south and offshore (Fonda Umani *et al.*, 1992). Hure *et al.* (1980) identified in the whole Adriatic Sea, the three main copepod communities: estuarine, coastal and oceanic.

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The main aim of this study was to analyze meso-zooplankton spatial distribution in relation to variability physico-chemical and biological factors; moreover, community structure was analyzed in order to identify some trophic feature typical of the northern and central Adriatic neritic system.

MATERIALS AND METHODS

Study Area

The northern Adriatic basin is delimited toward south transversely to Ancona, with varying depths from a minimum of 30 m to a maximum of about 70 m (Franco, 1983). The water masses circulation and distribution are tightly influenced by bottom morphology (Artegiani *et al.*, 1993; Franco *et al.*, 1982), by metereological conditions (Buljan and Zore-Armanda, 1976; Franco, 1973, 1983; Franco *et al.*, 1982) and by the remarkable fresh water contributions flowing from the Italian coasts (Fonda Umani *et al.*, 1994). During most of the year, in the nothern basin a frontal system is established (Franco, 1983; Fonda Umani *et al.*, 1992), which clearly separates neritic eutrophic waters from oligo-mesotrophic offshore ones, producing two independent and ecologically different systems (Fonda Umani *et al.*, 1994). These characteristics determine abundance and vertical stability cyclic variations of the water column, causing in winter time a complete instability, while during the rest of the year a clear stratification is evident (Fonda Umani *et al.*, 1992).

Sampling Procedures

In the framework of the Prisma II Project, two oceanographic cruises were carried out in the northern Adriatic (June, 1996 and February, 1997). The former zone north off Ravenna (area A), and the latter north off Ancona (area B). A total of 204 samples were collected by an electronic multinet BIONESS in 54 stations, located along inshore-offshore sections (Fig. 1a,b). The BIONESS with 0.25 m^2 of mouth width and 5 nets of 230 μm mesh size, was towed at a speed of 1–1.5 m s^{-1}. Samples were caught at 5–10 m intervals, depending on bottom depth. Technical BIONESS features have been described in Guglielmo *et al.* (1998). On board, samples were preserved with buffered formaldehyde 4% sea water solution.

Samples Analysis

In laboratory, a quali-quantitative analysis of meso-zooplankton was carried out on subsamples from 1/10 to 1/20, depending on the total sample richness, which was entirely observed for rare species identification. The specimens were sorted and divided per taxa. The taxonomic groups, identified to species level, were: copepods (adults) and cladocerans; the remaining groups were classified to taxa level. Biomass, as dry weight, was estimated using 500 ml of the whole sample, according to Lovegrove's method (1966). Abundance was expressed as ind m^{-3}, and biomass as mg m^{-3}. In some samples, biomass estimates were undermined by the presence of mucilaginous organic substance.

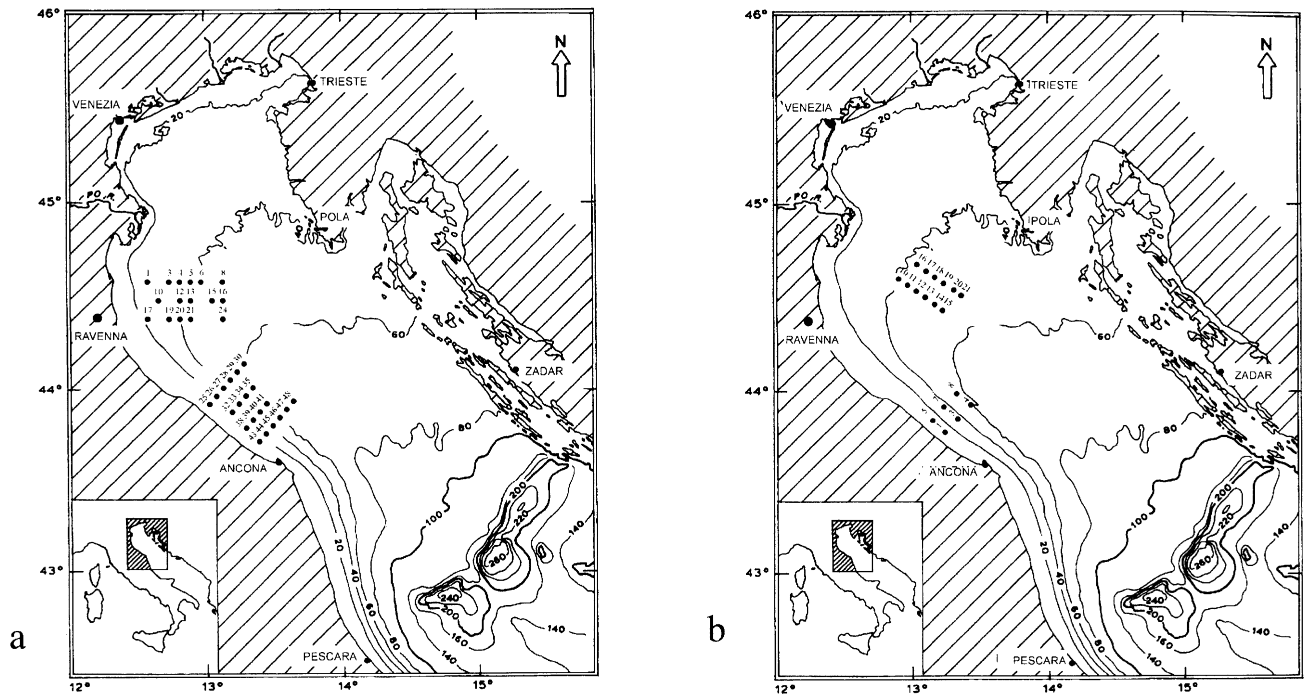

FIGURE 1 Sampling area and stations location during the northern adriatic cruises. a) June sampling b) February sampling.

RESULTS

Abundance, Biomass and Spatial Distribution

I CRUISE, JUNE, 1996. Mean values and standard deviation of abundance and biomass in the whole area, were 3857 ± 4702 ind m^{-3} and 29.1 ± 22.1 mg m^{-3}. In the area A, a zooplankton mean abundance of 2787 ± 1735 ind m^{-3} was found. Biomass, ranged from 5.9 mg m^{-3} to 173.2 mg m^{-3} (average 29.3 ± 26.7 mg m^{-3}). Zooplankton community was mainly constituted by copepods (1364 ± 883 ind m^{-3}) and cladocerans (605 ± 1053 ind m^{-3}) which reached 49% and 22% of the entire zooplankton community. Following, in order of abundance, doliolids (296 ind m^{-3}), dinoflagellates (*Noctiluca scintillans*, 219 ind m^{-3}), siphonophores (106 ind m^{-3}) and larvae of invertebrates (80 ind m^{-3}). Zooplankton abundance and biomass at the surface layers (0–10 m), showed an inshore-offshore decreasing gradient (4298 ind m^{-3} and 26.6 mg m^{-3} in the coastal stations and 2610 ind m^{-3} and 14.9 mg m^{-3} in the open sea). Particularly, this gradient was determined by a higher cladoceran average abundance, in the neritic stations (2388 ind m^{-3}), which strongly reduced in the offshore stations (555 ind m^{-3}). Vertical zooplankton abundance was characterized by a surface-bottom decreasing trend (Fig. 2a); at the surface at higher cladoceran abundance was detected while copepods were the dominant group at deeper layers. Biomass values showed, instead, a maximum of 36.7 mg m^{-3} in the 10–20 m layer (Fig. 2b).

In the Area B, the average biomass was 25.41 ± 15.3 mg m^{-3}, ranging from 9.1 mg m^{-3} to 81.2 mg m^{-3}. An average abundance of 4698 ± 5978 ind m^{-3} was detected, with an inversion of dominance ratio, compared to the area A, between cladocerans and copepods (3151 ± 5554 ind m^{-3}, 67% and 672 ± 286 ind m^{-3}, 14%). doliolids (200 ind m^{-3}; 4%), larvae of invertebrates (181 ind m^{-3}; 4%), appendicularians (171 ind m^{-3}; 4%) and siphonophores (148 ind m^{-3}; 3%) followed as order of abundance. Zooplankton distribution, at the surface layers (0–10 m), showed also in this area a decreasing inshore-offshore gradient, with an average abundance and biomass of 9108 ind m^{-3} and 36.4 mg m^{-3} at the neritic stations and of 5694 ind m^{-3} and 28.2 mg m^{-3} at the offshore ones. This trend was determined by a higher cladoceran abundances at the inshore stations (7422 ind m^{-3}). Zooplankton vertical distribution, in the investigated area, was characterized by a surface-bottom decreasing gradient determined by a strong decrease of cladoceran abundance, while copepods showed similar values along the whole water column (Fig. 2c). Biomass values showed as well a similar trend but the maximum of 24.1 mg m^{-3} was recorded close to the bottom (Fig. 2d).

II CRUISE, FEBRUARY, 1997. During this period, at both sampled areas, any remarkable differences were not detected, either for the total zooplankton abundance and the biomass. Values from 1380 ± 595 ind m^{-3} to 969 ± 493 ind m^{-3} and from 19.6 ± 9.88mg m^{-3} to 9.9 ± 3.2 mg m^{-3} were detected. The zooplankton community was mainly constituted by copepods (70%), followed by larvae of invertebrates, appendicularians and cladocerans. Zooplankton abundance and biomass distribution, along the water column, showed similar trends (Fig. 3a–d).

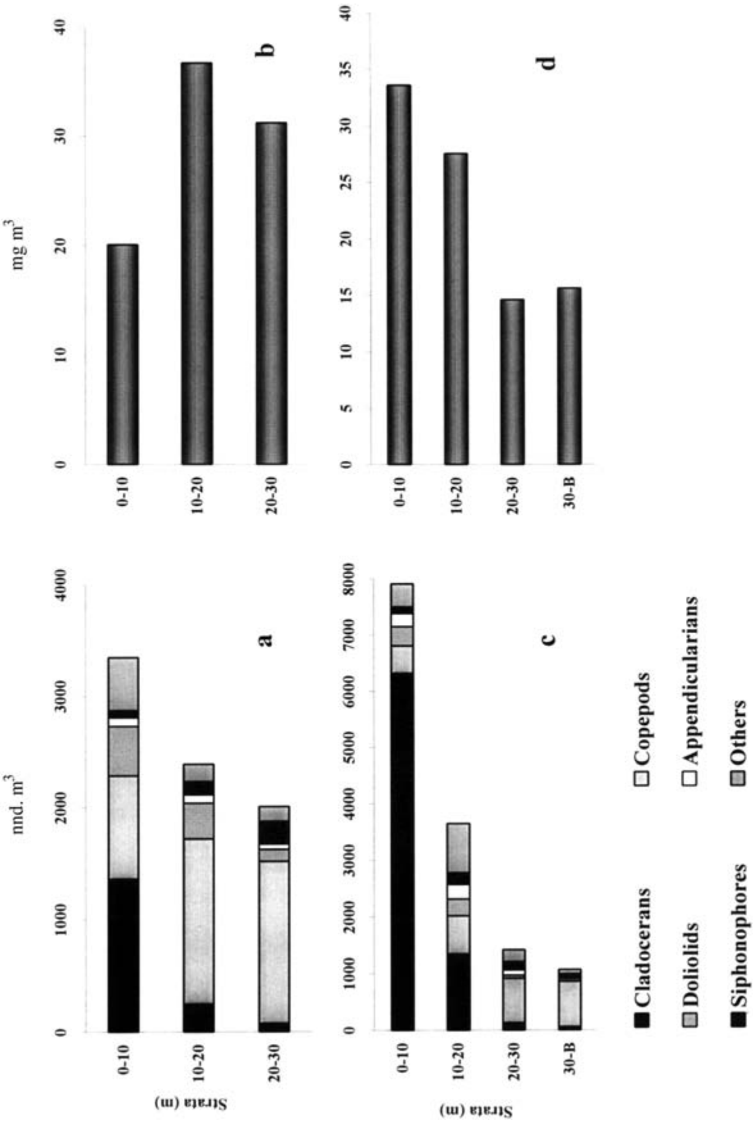

FIGURE 2 Zooplankton abundance (ind m $^{-3}$) and biomass (mg m $^{-3}$) in June cruise.

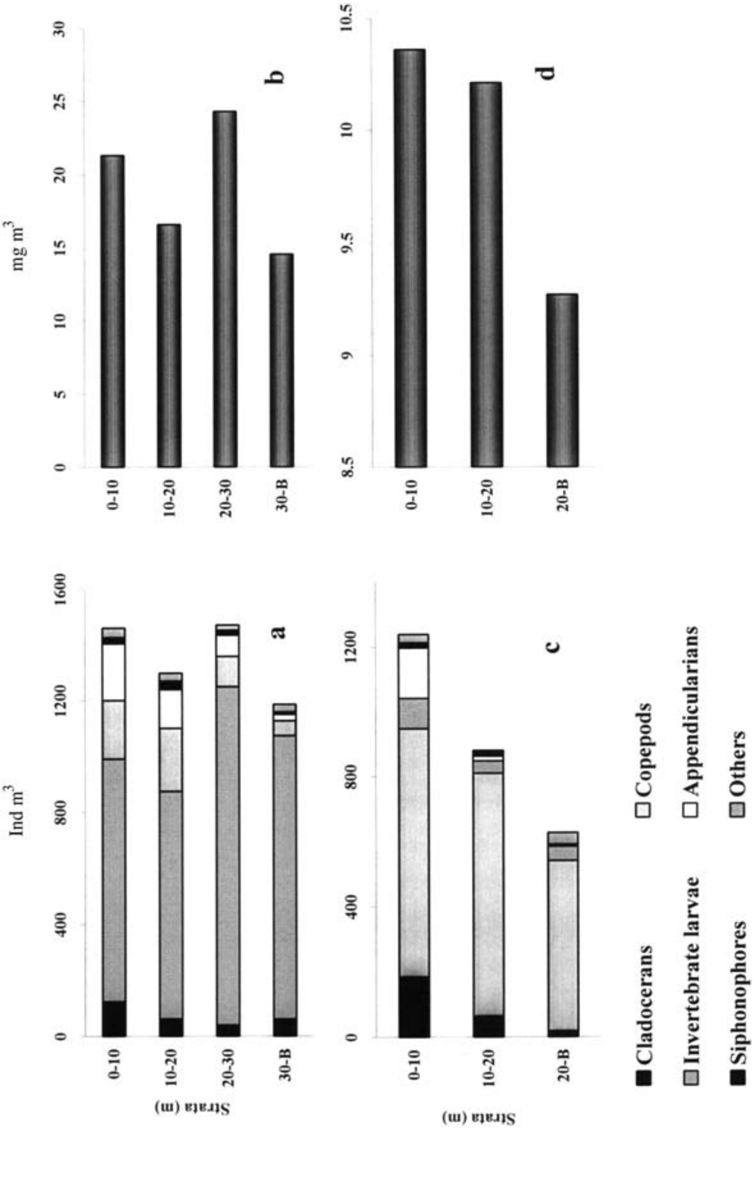

FIGURE 3 Zooplankton abundance (ind m $^{-3}$) and biomass (mg m $^{-3}$) in February cruise.

DISCUSSION

Zooplankton spatial distribution, in the northern and middle Adriatic Sea, is strongly influenced by the hydrological characteristics of the different water masses.

During the summer period, the fresh waters and nutrient input flowing into the basin from the Po River, determines the formation of two separated systems having clearly different hydrological and ecological characteristics (Fonda Umani *et al*., 1992, 1994; Franco, 1983). During this season zooplankton showed inshore-offshore and surface-bottom decreasing trends mainly due to the cladoceran, *Penilia avirostris*. The neritic system was characterized by a pycnocline, at around 10 m of depth, which separated surface warmer waters, enriched in nutrients, from deeper colder and saltier waters. The structure of the zooplankton community was dominated by *P. avirostris*, *A. clausi* and *P. parvus*, opportunist species which to the maximum values of primary productivity (spring–summer period), and increase their reproductive rate (Scotto di Carlo *et al*., 1985). The neritic waters, inside the frontal system and under the pycnocline, were characterized by the dominance of the copepods, *Calanus helgolandicus*, *C. vanus, T. longicornis* and *P. elongatus*.

During the winter period, when the vertical mixing of water masses occurred, both a lower zooplankton abundance and a more homogeneous spatial distribution were detected. Zooplankton structure was characterized by a high dominance of copepods. In this period, the population was characterized by a higher diversity among the genus *Oithona*, *Clausocalanus*, *Ctenocalanus*, *Calanus* and *Oncaea*. These epipelagic species showed, during the year, one or more reproduction periods not related to any increase of the primary production rates. They were found together with neritic species such as *A. clausi* and *P. parvus*. Scarce winter phytoplankton abundances should be a limiting factor for the quick numeric increase of the species of this genus, which followed one another during the year characterizing a different seasonal period (Scotto di Carlo *et al*., 1985). The high zooplankton biomass found in the North Adriatic Sea are due to the proliferation of tolerant non-selective feeding zooplankton species, such as copepods, which can use detritus as an important fraction of their diet. High concentration of the living and non-living particulate organic matter in addition to a high phytoplankton biomass, sustained by the availability of nutrients, contributes to the nutritional base for the zooplankton. In fact, several studies stated that detritus can form the main proportion of some copepod's diet even though detritus is presumably inferior to phytoplankton as a food source (Benovic *et al*., 1984). Summer zooplankton vertical distribution, allowed us to formulate a preliminary model about distribution, along the water column, of the different associations of species assemblages with regard to different water masses in the neritic system (Fig. 4).

The coastal-neritic area presents high biomasses and low species diversity. In the surface waters, the plankton biocenosis was characterized by the dominance of fine filter feeders as tunicates (*Oikopleura, Salpa* and *Doliolum*) and cladocerans (*P. avirostris*, *E. spinifera* and *E. tergestina*) that feed on the nanoplankton fraction (Fonda Umani *et al*., 1992) and mixtivorous copepods (*A. clausi* and *P. parvus*) able to feed on nano-, micro-zooplankton and particulate organic matter.

Below the thermocline, both copepods herbivorous species (as *Ctenocalanus vanus* and *Clausocalanus furcatus*), which mainly feed on diatoms, and carnivorous species (as

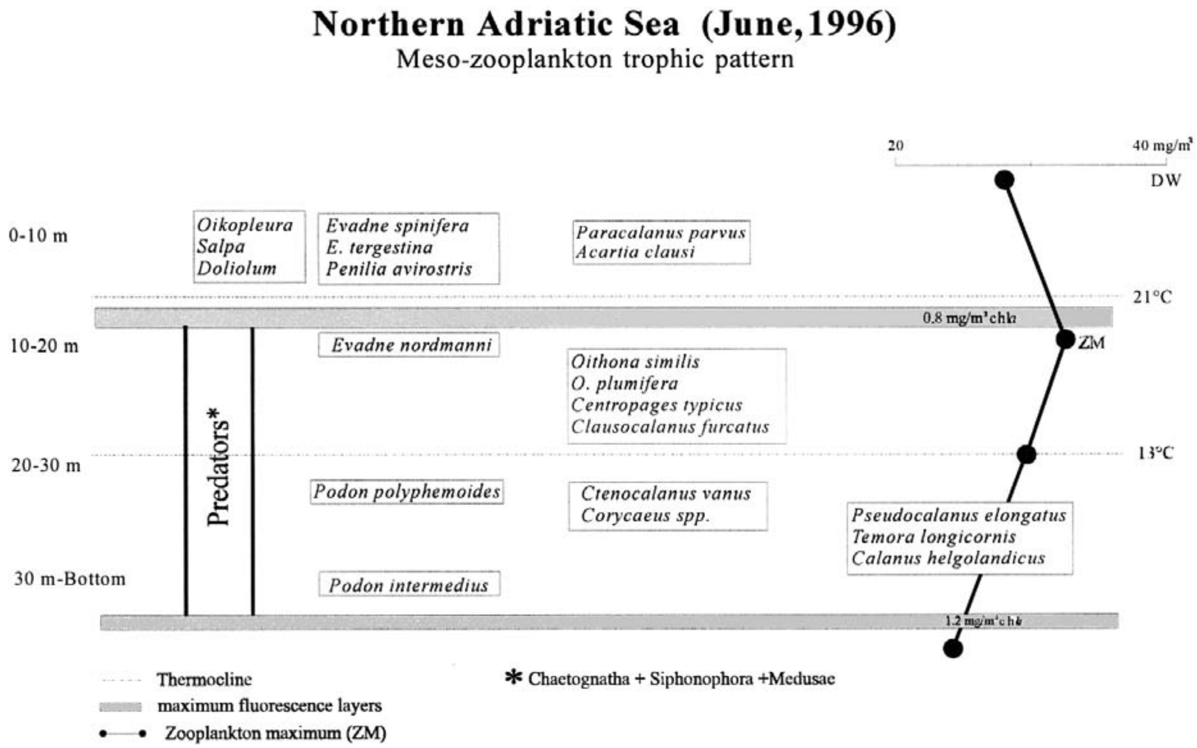

FIGURE 4 Depth distribution of zooplankton species having taxonomic and trophic similarities (June, 1996, cruise).

Oithona similis and *O. plumifera* and *Centropages typicus*, Fonda Umani *et al*., 1992) dominated, as well as a less rich surface community.

Close to the bottom, the species composition was characterized by herbivorous species and/or mixtivorous like *Pseudocalanus elongatus, Temora longicornis* and *Calanus helgolandicus*, that generally feed on diatoms, together with species typically carnivorous, of genus*Corycaeus*, *Oncaea* and *Podon*.

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