Available online at www.sciencedirect.com
SCIENCE DIRECT®
Science of the Total Environment 353 (2005) 218–231
Science of the Total Environment
An International Journal for Scientific Research into the Environment and its Relationship with Humankind
www.elsevier.com/locate/scitotenv

Inter-annual variations of planktonic food webs in the northern Adriatic Sea

Serena Fonda Umani [a,*], Luisella Milani [a], Diego Borme [a], Alessandra de Olazabal [a], Stefania Parlato [a], Robert Precali [b], Romina Kraus [b], Davor Lučić [c], Jakica Njire [c], Cecilia Totti [d], Tiziana Romagnoli [d], Marinella Pompei [e], Monica Cangini [e]

[a] *Laboratorio di Biologia Marina, Via A. Piccard 54, 34010 Trieste, Italy*
[b] *Center for Marine Research, Rudjer Boskovic Institute, G. Paliaga 5, 52210 Rovinj, Croatia*
[c] *Laboratory of Plankton Ecology, Institute of Oceanography and Fisheries, Kneza Damjana Jude 12, 20000 Dubrovnik, Croatia*
[d] *Dipartimento di Scienze del Mare, Università Politecnica delle Marche, Via Brecce Bianche, 60131 Ancona, Italy*
[e] *Centro Ricerche Marine, Viale Vespucci 2, 47042 Cesenatico, Italy*

Available online 28 October 2005

Abstract

The temporal dynamics of microphytoplankton, microzooplankton and mesozooplankton were monitored over 37 months in the Adriatic Sea in order to identify alterations in the plankton structures, which can lead to, or enhance the production of macro-aggregates, that affected the entire northern basin in summers 2000 and 2002, and to assess any negative effects of mucilage on plankton temporal patterns. Samples were collected monthly, from June 1999 to July 2002, on three transects at 9 stations across the northern and central Adriatic Sea. Besides the high year-to-year variations in abundances and taxonomical composition, plankton communities only showed a clear seasonal succession during 2001, when since April a grazing food web developed and was able to control large sized phytoplankton increase. In spring–summer 2000 and 2002 consumer abundances remained quite low and the dominant mesozooplankton summer species (*Penilia avirostris*) did not reach its usual summer maximum. The lack of an efficient top control was more evident on the northernmost transect, where generally grazing food web prevails over the microbial one. A large part of the microphytoplankton blooms, although not particularly intense, was exported to the bottom in the particulate phase, where it was processed by bacteria, enhancing the production of refractory dissolved material.

Keywords: Plankton communities; Adriatic Sea; Mucilage; Temporal dynamics

1. Introduction

Plankton size and functional classes play essential roles in the organic carbon flux through pelagic food webs (e.g., Legendre and Le Fevre, 1992). The size of photosynthetic producers, i.e. large (>2–5 μm) or small (<2–5 μm) phytoplankton, and the nature of dissolved organic carbon (DOC) produced (labile or refractory), can strongly influence the partitioning of biogenic carbon between the short-lived (microbial food web), long-lived (grazing food chain; Azam, 1998) or sequestered pools (refractory DOC and biogenic sedimented matter; Legendre, 1996).

Remarkably, in shallow turbulent environments, like the northern Adriatic, where increased nutrient availability is episodic, the microbial or the grazing food

* Corresponding author. Tel.: +39 040 224 989; fax: +39 040 224 9870.
E-mail address: labbioma@univ.trieste.it (S. Fonda Umani).

0048-9697/$ - see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.scitotenv.2005.09.016

web can alternately dominate in the carbon flow over short time periods. In spring, as a result of episodic nutrient enrichment of the euphotic zone and insufficient grazing, as a controlling factor of their population size, large-sized phytoplankton blooms occur. On the opposite, microbial food web is typical of low energy environment, mostly based on regeneration processes (Kiørboe, 1996). As a consequence, the final fate of photosynthesised carbon can strongly change over time in the same environment as a function of the planktonic food web structures.

The northern Adriatic is one of the most productive Mediterranean regions at several trophic levels, from phytoplankton to fish. Particularly, the area of marked, but variable, plankton standing crop and production was quantified off the Po River delta and related to the spreading of its plume (Franco, 1973; Gilmartin and Revelante, 1981; Smodlaka and Revelante, 1986; Degobbis et al., 2000). All plankton biomasses show a strong decreasing gradient from the Po River eastwards, as well as from northern Adriatic southwards, whereas a reverse gradient is evident for plankton diversity (Fonda Umani, 1996).

Microphytoplankton is mostly constituted by diatoms that vary temporally and spatially with intermittent riverine inputs and generally show two maxima (winter–spring and autumn) throughout the water column, more evidently in the coastal waters. Nanoplankton is numerically dominant throughout the entire Adriatic Sea, more abundantly in the northern part and along the coasts. Coccolitophorides are associated with Ionian input waters and are more abundant in the southern part. Dinoflagellates are characteristic of the summer period, although their abundance never reaches high values, with the exception of "red tide" phenomena that were reported almost every year during the 1970s, along the western coast (Emilia Romagna Region, Italy), and less frequently in other northern Adriatic coastal areas (Sellner and Fonda Umani, 1999). In the 1970s, nutrient loading by the Po River significantly increased, reaching the highest concentration in the early 1980s (Harding et al., 1999). At the end of the 1980s, we observed a shift from red tides to mucilage phenomena, which affected the whole northern basin in 1988, 1989, 1991, 1997, 2000 and 2002 (Degobbis et al., 1995, 1999; Precali et al., 2005—this issue).

Microzooplankton composition in the northern Adriatic is characterized by the dominance of ciliates other than tintinnids (Revelante and Gilmartin, 1983, 1985), southwards tintinnids become more important.

In the northern basin, mesozooplankton is characterized by high percentage of meroplankton, and strictly neritic copepod and cladoceran species, low diversity, and clear prevalence of *Penilia avirostris* in the summer and *Acartia clausi* during the rest of the year. Southwards diversity increases as well as abundance of the "oceanic" species, and *Paracalanus parvus* becomes prevalent (Malej, 1979; Hure et al., 1980; Specchi and Fonda Umani, 1983, 1987; Lučić et al., 1988; Ghirardelli et al., 1989; Fonda Umani et al., 1992, 1994; Fonda Umani, 1996; Hure and Kršinić, 1998).

Regarding the food web structure, Del Negro et al. (2001) found a high number of relationships among different classes of prey and predators in the coastal northern Adriatic area in the spring, when the increase of primary production enhances the predation rates, thus resulting in a more efficient transfer of energy towards the upper level consumers.

The main goal of this paper was to define the structural changes of the plankton community that occurred in the northern Adriatic Sea over a 37-month period (from June 1999 to July 2002), as well as to highlight possible significant differences among the years with (i.e. 2000 and 2002) and without mucilage events (i.e. 1999 and 2001). We analyzed the temporal evolution of microphytoplankton, microzooplankton and mesozooplankton communities, their mutual relationships, as well as total abundance and taxonomical composition.

Analyses of the plankton system were carried out bearing in mind that

(1) the mucilage appears all along the water column and impacts the entire northern Adriatic sub-basin
(2) alterations in the plankton structures, which can lead to, or enhance the production of macroaggregates, must be recognizable at the same spatial and temporal scale
(3) negative effects of mucilage on the temporal plankton dynamics has to be noted at a sub-basin wide scale.

2. Material and methods

Samples were collected monthly, from June 1999 to July 2002, on three transects at 9 central stations (A03, A07, A11, B06, B10, B13, C04, C07, C12), across the northern (transect A) and central (transects B and C) Adriatic Sea (Fig. 1). Water samples (5 L) for microphytoplankton and microzooplankton analysis were collected with Van Dohrn (transect A) and Niskin (transects B and C) bottles at three standard depths (surface, 10 m and 2 m above the bottom).