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ORIGINAL RESEARCH ARTICLE

Influence of the winter phytoplankton bloom on the settled material in a temperate shallow estuary

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Summary The development of the phytoplankton winter bloom and the accumulation of particulate suspended matter (PSM) inside sediment collectors were assessed in the inner zone of the Bahía Blanca Estuary. The phytoplankton bloom (chlorophyll up to 25 μg l^{-1} and abundance up to 8×10^6 cells l^{-1}) was related with high levels of dissolved inorganic nutrients and underwater light availability (I_m up to 355 μE m^{-2} s^{-1}) and was dominated by relatively small diatoms, e.g. *Chaetoceros* sp.1 (3—8 μm). Conversely, large planktonic diatoms, mostly *Thalassiosira* spp. 20—60 μm, were found in the accumulated material inside the collectors, together with benthic microalgae and high concentrations of chlorophyll, phaeopigments, particulate organic matter (POM between 18 and 32% of total PSM) and C:N ratios >12. The composition of the settled material indicated vertical exportation of phytoplankton to the benthos, external loads of detritus and bottom resuspension. The present study highlights the close benthic-pelagic interactions in shallow coastal environments characterized by high productivity.

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1. Introduction

Spring phytoplankton blooms represent the most important annual impulse in the pelagic food webs in temperate coastal environments (Legendre, 1990). The fate of the organic matter produced in the euphotic zone determines the role of the biological pump in the carbon cycle, and the sedimentation of phytoplankton blooms can strongly influence the benthic habitat in coastal shallow systems (Davoult and Gounin, 1995; González et al., 2009). Sink deposition of particulate matter is affected by diverse physico-chemical and biological factors such as water column structure: stratified/mixed, temperature, turbidity, phytoplankton density, aggregate formation and zooplankton grazing (Cibic et al., 2007; Kiørboe et al., 2001, Tamelander and Heiskanen, 2004). In oceans, most of the organic matter produced in the upper layers is consumed before reaching the bottom sediments (Legendre and Rassoulzadegan, 1996; Wassmann, 1998), while in coastal shallow and well mixed systems, a tight interaction between the production in the water surface and the benthic habitat is commonly observed (Botto et al., 2006; Dale and Prego, 2002). In addition, the underlying sediments may contribute to the pelagic habitat with dissolved nutrients, organic matter and microphytobenthos through resuspension induced by winds and tides (de Jonge and van Beusekom, 1995). Furthermore, high loads of allocthonous material into the pelagic environment are expected from different sources: terrestrial, littoral and river discharges (Fahl and Nöthig, 2007; Montemayor et al., 2011).

In the temperate and eutrophic Bahía Blanca Estuary, the phytoplankton seasonality and composition has been studied for decades and the winter-early spring bloom has been characterized as the most important biomass event over the annual cycle (Guinder et al., 2010 and references therein). The inner zone of the estuary is the most productive area along the main channel, as a result of high abundance and diversity of both planktonic and benthic communities (Elías, 1992; Hoffmeyer et al., 2008; Popovich and Marcovecchio, 2008). In this shallow inner zone, a tight benthic–pelagic coupling is expected. For instance, resting stages of diatoms (Guinder et al., 2012) and zooplankton resting eggs (Berasategui et al., 2013) have been found lying in the sediments and germinating in the pelagic habitat after resuspension. Conversely, a marked difference in the species composition has been found between plankton and benthos: the phytoplankton is dominated by centric diatoms while the dense microbial mats are densely formed by pennates diatoms and cyanobacterias (Pan et al., 2013; Parodi and Barría de Cao, 2003). This suggests low exportation of phytoplankton cells to the bottom either by intense grazing in the water column or high degradation processes of the organic matter. However, little is known so far on vertical transport of phytoplankton and organic matter; only short-term observations have been done during a tidal cycle (Guinder et al., 2009a). Tracking the production and fate of the organic matter produced in the surface of the water column during the blooming season will elucidate the potential benthic–pelagic interactions and the remineralization capacity of the system in the highly productive inner zone of the Bahía Blanca Estuary. In this work our goals were (1) to evaluate the evolution of the winter-early spring phytoplankton bloom in surface waters assessing the species succession, size structure, duration and magnitude of the bloom in relation to environmental factors, and (2) to characterize the settled material inside sediment collectors in terms of accumulated particulate suspended matter (PSM) and organic matter (POM), chlorophyll and phaeopigments concentrations, and carbon-to-nitrogen ratios (C:N). Overall, we aim to obtain an approach to the modulating factors of the winter phytoplankton bloom and its potential influence in the underlying sediments.

2. Material and methods

2.1. Study area

The Bahía Blanca Estuary (38°42′–39°25′S, 61°50′–62°22′W) is located in a temperate climate region on the southwestern Atlantic, Argentina. The estuary is mesotidal (mean tidal amplitude of 3.5 m) with a semidiurnal cycle, highly turbid and eutrophic (Freije and Marcovecchio, 2004; Guinder et al., 2009b). The sampling site, Puerto Cuatreros station (38°50′S; 62°20′W), is a shallow harbor (mean depth: 7 m) located at the head of the estuary (Fig. 1) and characterized by a restricted circulation (tidal velocities between 0.69 and 0.77 $m\ s^{-1}$), low advection and a relatively long residence time (ca. 30 days). The river runoff is low; the Sauce Chico River, the main freshwater tributary, presents a mean annual runoff of 1.9 $m^3\ s^{-1}$, with maximum of 106 $m^3\ s^{-1}$ in autumn due to rainfalls, and the Napostá Grande Creek has an annual runoff of 0.8 $m^3\ s^{-1}$ (Melo and Limbozzi, 2008).

The maximal plankton biomass of the estuary is found in the inner zone of the estuary (Barria de Cao et al., 2005; Berasategui et al., 2013; Popovich and Marcovecchio, 2008) which is highly eutrophic due to important inputs of organic matter, detritus and nutrients from anthropogenic sources (industrial, urban and agricultural activities) (Freije et al., 2008) and saltmarshes (Montemayor et al., 2011; Negrin et al., 2013). In this area, numerous interconnected channels separate small islands and vast tidal flats and saltmarshes with halophytes of the species *Sarcocornia perennis*, *Spartina alterniflora* and *S. densiflora* (Isacch et al., 2006). The extensive bare flats are mainly composed of silt-clay sediments covered with dense microbial mats (Cuadrado and Pizani, 2007; Parodi and Barría de Cao, 2003). Benthic fauna is dominated by *Laeonereis acuta*, a deposit-feeder polichaete, and the burrowing crab *Neohelice granulata* (Escapa et al., 2007).

2.2. Sampling at the surface water

The sampling was carried out on a fortnightly frequency from January to December 2007 at Puerto Cuatreros station, during midday and high tides. Mean depth of the sampling station was 7 m. Surface water temperature was measured in situ using a portable Horiba U-10 multi-probe (Horiba Ltd., Kyoto, Japan). Water samples were collected from the surface (approx. 0.5 m depth), using a van Dorn bottle (2.5 l), stored in a cooler and taken to the laboratory to estimate phytoplankton abundance, chlorophyll *a* (chl), phaeopigments (pha) and dissolved inorganic nutrient concentrations (nitrate, nitrite, phosphate and silicate) and particle size