Marine Pollution Bulletin xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Microplankton dynamics under heavy anthropogenic pressure. The case of the Bahía Blanca Estuary, southwestern Atlantic Ocean

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ARTICLE INFO

Article history:
Available online xxxx

Keywords:
Microplankton
Eutrophication
Estuaries
Nutrient stoichiometry
Climate
Path analysis

ABSTRACT

Quantifying biotic feedbacks in response to environmental signals is fundamental to assess ecosystem perturbation. We analyzed the joint effects of eutrophication, derived from sewage pollution, and climate at the base of the pelagic food web in the Bahía Blanca Estuary (SW Atlantic Ocean). A two-year survey of environmental conditions and microplankton communities was conducted in two sites affected by contrasting anthropogenic eutrophication conditions. Under severe eutrophication, we found higher phytoplankton abundance consistently dominated by smaller sized, non siliceous species, while microzooplankton abundance remained lower and nutrient stoichiometry showed conspicuous deviations from the Redfield ratio. Phytoplankton growth in such conditions appeared controlled by phosphorous. In turn, microplankton biomass and phytoplankton size ratio (<20 μm:>20 μm) displayed a saturation relationship with nutrients in the highly eutrophic area, although mean phytoplankton growth was similar in both eutrophic systems. The strength of links within the estuarine network, quantified through path analysis, showed enhanced relationships under larger anthropogenic eutrophication, which fostered the climate influence on microplankton communities. Our results show conspicuous effects of severe sewage pollution on the ecological stoichiometry, i.e., N and P excess with respect to Si, altering nutrient ratios for microplankton communities. This warns on wide consequences on food web dynamics and ultimately in ecosystem assets of coastal pelagic environments.

1. Introduction

Estuaries are exposed to multiscale biotic and abiotic factors heavily affected by anthropogenic forces. Among human induced environmental changes, coastal eutrophication constitutes a major challenge to these ecosystems due to the consequences on biomass and structure at the base of food webs. In addition, eutrophication is likely to increase in the near future along with enhanced anthropogenic activities in coastal areas (Rabalais, 2004). The cumulative effect of climate change (i.e. ocean warming and acidification, sea level rise) and the occurrence of sudden climate events (i.e. extreme rainfall, drought, flooding) therefore warn on the potential vulnerability of estuarine systems (Paerl et al., 2006; Rabalais et al., 2009). Long term environmental surveys that integrate the entire trophic network are therefore essential to supply reliable data to quantitatively assess, and eventually forecast, the impact of anthropogenic and climate disturbances in estuaries.

Nutrient loading in coastal habitats promotes an increase in the magnitude and frequency of phytoplankton blooms (Cloern, 2001). Irregular nutrient pulses result in the occurrence of discrete productivity events, which may be accompanied by a trophic mismatch (Strom, 2002). An increase in phytoplankton biomass due to nutrient loading is associated with changes in the elemental stoichiometry of cells. Depending on the environmental ratio of nutrients, the C:nutrients ratio of phytoplankton community may shift affecting food quality for primary consumers (Sterner and Elser, 2002; Elser et al., 2010). Eventually these changes propagate throughout the entire food web, as the grazing potential of

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http://dx.doi.org/10.1016/j.marpolbul.2015.03.026
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consumers determines the magnitude of phytoplankton biomass accumulation and the energy transfer in the pelagic environment.

The Bahía Blanca Estuary is a highly productive and eutrophic ecosystem in the southern Atlantic Ocean, heavily impacted by anthropogenic activities (Marcovecchio et al., 2008). Industrial and domestic waste is being dumped in the inner estuary, while human activities are rapidly growing in the area. Consequently, coastal eutrophication in the inner estuary appears responsible of a considerable reduction on zooplankton abundance and diversity (Barría de Cao et al., 2003; Biancalana et al., 2012; Dutto et al., 2012). Eutrophication effects on zooplankton may further magnify the climate influence, which affects both the physical environment of plankton, as well as the physiological rates of these organisms. Indeed, changes in phenology and structure of phytoplankton and zooplankton, i.e. timing of seasonal peak, species composition and cell sizes, have been ascribed to regional climate modifications (Hoffmeyer, 2004; Guinder et al., 2010, 2013).

Joint effects of multiscale environmental signals shape the structural and functional outcome of populations, and have the potential to move the entire ecosystem towards alternative stable states (Scheffer and Carpenter, 2003). In particular, plankton is sensitive to a wide range of biophysical variables, and can quickly transfer environmental signals into the pelagic food web (Prairie et al., 2012). Their effect however may be either buffered, through compensatory dynamics (Gonzalez and Loreau, 2009), or amplified via trophic tunneling (Taylor et al., 2002). Hence, to resolve how eutrophication gradients modify the pelagic configuration at the base of the food web requires the quantification of interlinks and biotic feedbacks in the estuarine network. We here investigate the microplankton dynamics under varying anthropogenic pressures in the Bahia Blanca Estuary, and test the hypothesis that heavy eutrophication magnify climate effects on microplankton communities, further modifying the network links at the base of pelagic food webs.

2. Materials and methods

2.1. Study area

The Bahía Blanca Estuary (38°45′–39°40′S, 61°45′–62°30′W) is located in the south western Atlantic Ocean coast, Argentina (Fig. 1). This area shows a temperate climate, marked seasonality and relatively low annual rainfall (ca. 613 mm) that mainly occurs during spring and autumn (Montecinos et al., 2000). The estuary shows inverted salinity gradient as it experience low influence from continental drainage (annual mean 2.7 $m^3\,s^{-1}$), high evaporation rate and restricted water circulation in the inner reach (Perillo et al., 2001). Salinity in the inner and middle estuary range between 17.9 and 41.3, and appear driven by the variability of

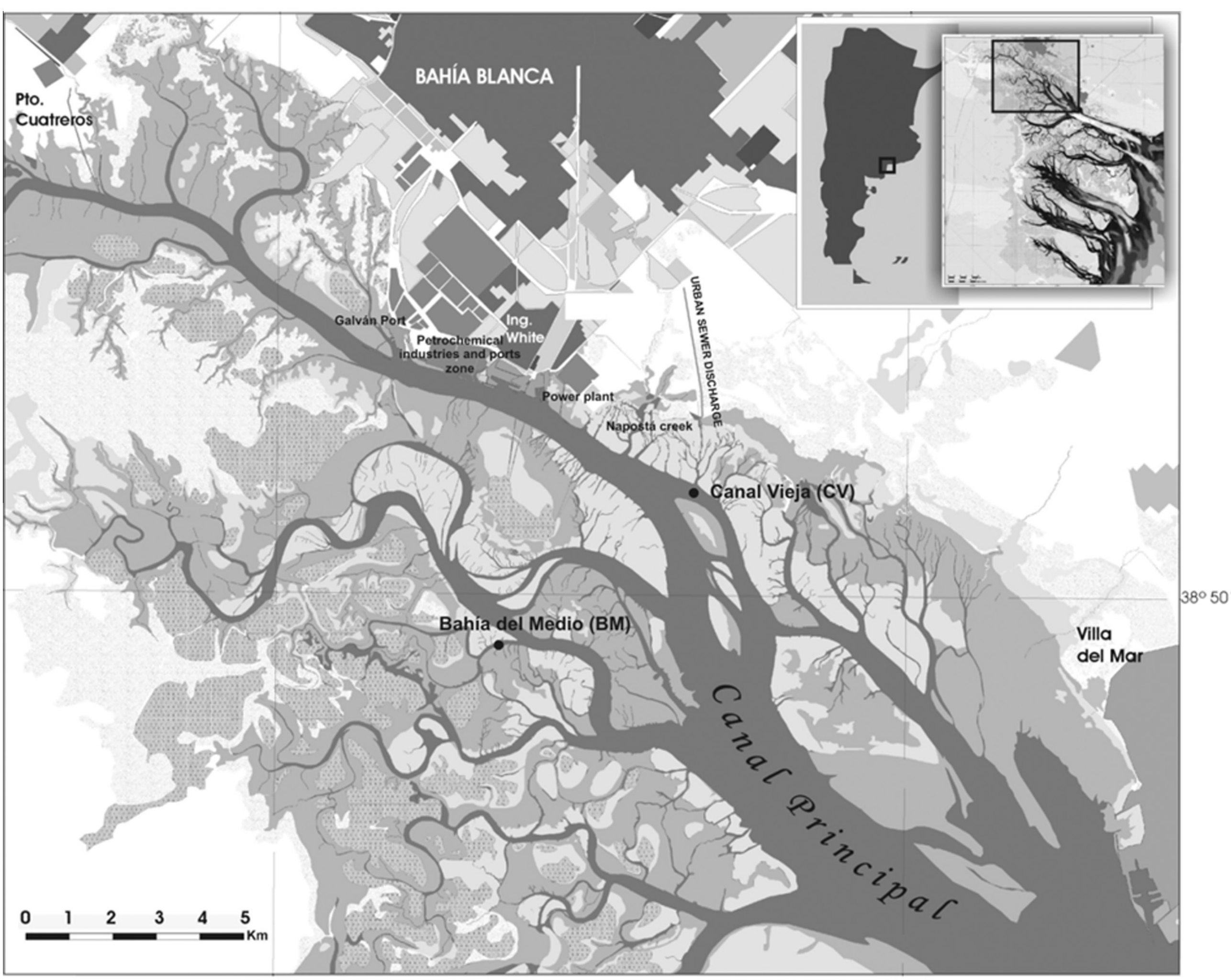

Fig. 1. Sampling area showing the location of the highly impacted site "Canal Vieja" (CV) and the control site "Bahía del Medio" (BM).

Please cite this article in press as: López Abbate, M.C., et al. Microplankton dynamics under heavy anthropogenic pressure. The case of the Bahía Blanca Estuary, southwestern Atlantic Ocean. Mar. Pollut. Bull. (2015), http://dx.doi.org/10.1016/j.marpolbul.2015.03.026