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Phytoplankton community structure in relation to hydrographic features along a coast-to-offshore transect on the SW Atlantic Continental Shelf

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ABSTRACT

The continental shelf in Southern Brazil is characterized by high biological productivity associated with horizontal and vertical density gradients due to the mixing of distinct water masses. Phytoplankton biomass and composition were evaluated in summer 2013 along an on-offshore transect off the mouth of the Patos Lagoon (Lat. 32°12S). Photosynthetic active radiation, temperature, salinity and fluorescence vertical profiles were carried out and Brünt-Väisäla frequency was estimated. Three water bodies were identified: the Subtropical Shelf Water along the entire transect, the Plata Plume Water on the middle shelf surface and the Tropical Water farther offshore. The water was sampled (N = 40) for the analyses of dissolved inorganic nutrients, phytoplankton cell density and composition. Phytoplankton present in the water was identified and quantified by the classical microscope sedimentation technique, complemented with CHEMTAX analysis of high-performance liquid chromatography (HPLC) pigment data. From the results obtained, chlorophyll *a* concentration was higher at both coastal stations (1.6–2.0 mg m^{-3}) where the water column was homogeneous and diatoms dominated the stations. This group was replaced by dinoflagellates in stratified conditions on the shelf and farther offshore. Along the onshore-offshore gradient, two types of dinoflagellates were found: the peridinin-containing dinoflagellates *Prorocentrum* and *Scrippsiella* with a small contribution at the coastal stations, and the fucoxantin-containing small Gymnodiniales cells (< 15 μm) with more than 50% of the total chlorophyll *a* at the stations on the continental shelf, especially associated with the chlorophyll maximum at the base of the euphotic zone. The positive (negative) relationship between the biomass of dinoflagellates (diatoms) with the Brünt-Väisäla frequency, respectively, support the hypothesis that stratification is the most important environmental factor that determines the biomass of phytoplankton communities and distribution on the shelf and in coastal waters off Southern Brazil in summer. Picoplankton cells (*Prochlorococcus* and *Synechococcus*), recorded for the first time in the region under study, were predominant in the nutrient-poor and well-lit surface layers along the transect, indicating the importance of their low sedimentation rates (small size) and photo-adaptive strategies to survive on the upper layers of the water column.

1. Introduction

Horizontal and vertical gradients of water temperature, salinity, nutrients and phytoplankton biomass and composition in the Southwestern Atlantic Ocean are largely associated with the presence of distinct water masses (Brandini et al., 2014). Oceanographic fronts, mixing processes between distinct water masses and significant amount of freshwater input, which affect the availability of nutrients and consequent primary productivity (Ciotti et al., 1995), are the key drivers that support large fisheries on the Southern Brazilian shelf (Castello et al., 1990; Haimovici et al., 2006; Haimovici and Cardoso, 2017).

The continental shelf in Southern Brazil is characterized by high phytoplankton biomass and biological productivity associated with horizontal and vertical density gradients due to the mixing of distinct water masses (Ciotti et al., 1995; Odebrecht and Garcia, 1997; Castello et al., 1997; Gaeta and Brandini, 2006). In this region, the influence of warm Tropical Water and Subtropical Shelf Water, the cold Subantarctic Shelf Water and the low salinity coastal water of La Plata Plume (PPW) varies seasonally and spatially (Möller et al., 2008; Piola et al., 2008). On the coast, huge concentrations (10^8–10^9 cells L^{-1}) of the diatom *Asterionellopsis guyunusae* (formerly *A. glacialis*) are accumulated in the surf zone associated with southerly atmospheric fronts, storm waves and onshore winds (Odebrecht et al., 2010, 2014; Franco et al., 2016). Few studies of phytoplankton composition on the shelf indicate that high concentration in late winter and spring is associated with abundant diatoms (*Skeletonema costatum*) near the Patos Lagoon

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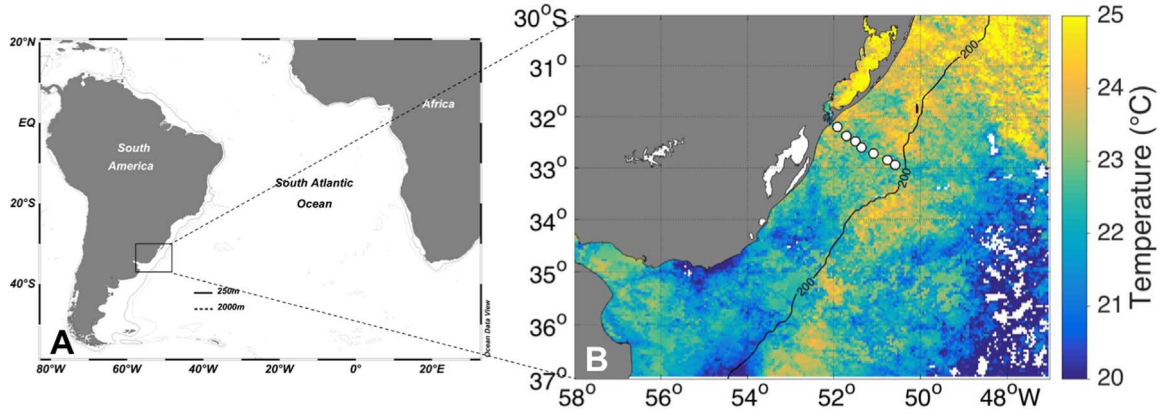

Fig. 1. The study area in Southern Brazil, SW Atlantic Ocean (A). Average weekly sea surface temperature obtained by the MODIS-Aqua satellite, spatial resolution 4 km with inserted sampled transect from the coast to the slope in austral summer (February 2013) (B).

mouth and armored dinoflagellates (*Scrippsiella trochoidea*, *Prorocentrum* spp., *Dinophysis* spp. and *Ceratium* spp.) under the influence of PPW (Odebrecht and Garcia, 1997; Islabão, 2010; Islabao and Odebrecht, 2011). In spring/winter, Ciotti (1990) observed high relative density of armored autotrophic/mixotrophic (*Heterocapsa*, *Scrippsiella trochoidea* and *Tripos*) and heterotrophic dinoflagellates (*Protoperidinium* spp., *Gyrodinium* spp.) in offshore regions on the SW Atlantic Continental Shelf. Farther south, on the coast of Uruguay, the water column stratification was designated as the main factor which determines shifts in the dominance between marine diatoms and dinoflagellates in spring (Ferrari, 2008) and, in Argentinean waters, dinoflagellate blooms were found in nutrient-rich waters, under low turbulence, linked with the presence of PPW (Carreto et al., 2008).

A complex hydrography of the region, with the existence of strong density gradients (Ciotti, 1990; Castello et al., 1990), resulting from proximity to the Subtropical Convergence and also by low salinity water, from La Plata River and Patos Lagoon estuary, establishes different associations of phytoplankton groups in an environmental gradient. In the summer, the concentration of nutrients is low under the influence of the Brazil Current (Niencheski and Fillmann, 1997), as well as the abundance of phytoplankton. Around 1100 spp. of microalgae have been registered for the region (Seelinger et al., 1997), among which are species that cause harmful blooms and/or are toxin-producing (Odebrecht et al., 1995; Persich et al., 2006; Haraguchi and Odebrecht, 2010). The presence of harmful species, mainly dinoflagellates, represent a potential inoculum to their blooms on the coast (Smayda, 2002). Several dinoflagellates are favored under the influence of lower salinity water (Carreto et al., 1995; Islabao and Odebrecht, 2011). Consequently, the study on their distribution and composition, improve the knowledge about regional ecosystems and phytoplankton communities. In the present study we analyze phytoplankton and environmental data collected along a coast-to-offshore transect off the mouth of the Patos Lagoon in Southern Brazil. Classical microscopy methods (appropriate for large cells) and HPLC-CHEMTAX approaches (for large and small cells) are used for evaluating the whole phytoplankton community. Within this context, we aimed to evaluate the main factors governing the phytoplankton community structure along a coast-to-offshore transect on the SW Atlantic Continental Shelf.

2. Material and methods

2.1. Study area

The continental shelf and slope off the mouth of the Patos Lagoon (Lat. 32°12S), Rio Grande, RS, Brazil, is influenced by the Tropical Water (TW), South Atlantic Central Water (SACW), Subantarctic Water (SAW), Subantarctic Shelf Water (SASW) and Subtropical Shelf Water (STSW). The thermohaline properties on the continental shelf also vary according to the freshwater volume discharged by major sources, such as the La Plata River plume (PPW) and the Patos Lagoon (PL) (Möller et al., 2008; Piola et al., 2008). The northward extension of PPW is related to the amount of continental water discharge and the wind regime (Möller et al., 2008), and strongly affects salinity, thermohaline circulation and stratification on the continental shelf (Matano et al., 2010; Piola et al., 2000). In the summer period, two STSW variables are formed due to mixing on the shelf of slope water with PPW (warm variable) and with SASW (cold variable) (Möller et al., 2008; Piola et al., 2000, 2008). Both SASW and STSW originate from the Subtropical Shelf Front (STSF), which is characterized by thermohaline gradients on the shelf slope perpendicular to the coast around 32°S, showing significant seasonal variability (Piola et al., 2008; Möller et al., 2008). The main nutrient sources in the region are from PPW (silicate and phosphate), SASW (nitrate and phosphate) and SACW upwelling (nitrate) (Braga et al., 2008). Periods of great precipitation (e.g., El Niño years) have been associated with an increase in chlorophyll *a* on the continental shelf (Ciotti et al., 1995).

2.2. Sampling

The oceanographic cruise was carried out in austral summer (February 20–23, 2013) between the coast and shelf slope off the mouth of the Patos Lagoon (Lat. 32°12S) (Figs. 1a, 1b). Vertical profiles of photosynthetic active radiation (PAR), temperature, salinity and fluorescence (Sea-Bird CTD/Carrousel 911+ system®; fluorescence sensor and PAR – *WetLabs ECO-AFL/FL*®) were determined at seven stations prior to water sampling with Niskin bottles.

Calculation of PAR attenuation coefficients (k-par) was based on an exponential decrease with depth at stations occupied during the day. The euphotic zone was estimated as the depth where the downwelling irradiance of PAR was 1% of the one just below the surface (Kirk, 1994).

At all stations, water samples for microscopy and nutrient analysis were collected with Niskin bottles at four depths, at least. The selection was based on fluorescence profiles: on the surface (1–2 m), deep chlorophyll maximum (DCM), below-DCM (where fluorescence levels stabilized at low values) and at an intermediate depth between the surface and DCM. Samples for the phytoplankton pigment analysis were collected on the surface and at fluorescence peak depths, at the stations where they could be detected. For instance, the most coastal stations (stations #1, #2 and #3) did not show an evident peak and, in order to have a second depth, additional sampling was performed on the subsurface (5–20 m).

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