MICROPLANKTON COMMUNITY STRUCTURE OF THE SHALLOW COASTAL ZONE AT ADMIRALTY BAY, ANTARCTICA: COMPARISON BETWEEN TWO CONSECUTIVE AUSTRAL SUMMERS

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Abstract: *The main objective of this work was to investigate interannual changes of phytoplankton structure as part of a long-term monitoring program in Admiralty Bay, Antarctic Peninsula. Based on microscopic analysis, phytoplankton taxonomic composition and biomass are investigated since 2009. This report presents results from the 2009/2010 and 2010/2011 summer surveys regarding the phytoplankton size-structure and biomass. Four scenarios were proposed in our study for environmental conditions and phytoplankton community: 1) 2009/2010 Early Summer; diatom growth was promoted by high Si:N, but inhibited by low N:P and low temperature, 2) 2009/2010 Late Summer; diatom growth was inhibited by low N:P and low Si:N, and high temperature and low N:P promoted dinoflagellates growth, due to their low optimum N:P ratios compared to diatoms; 3) 2010/2011 Early Summer; diatom growth was promoted by high N:P, high Si:N and high temperature and 4) 2010/2011 Late Summer; blooms of chain-forming diatoms (e.g. *Thalassiosira* spp.), favoured by high Si:N and high temperature, and it could explain the drastic reduction both in nitrate and silicate. The microplankton community of Admiralty Bay presented a high variability during the studied period that was clearly dictated by environmental factors. The time window covered by this study gives us only a glimpse of the direction of long term changes that the Antarctic environment might be experiencing. A more complete picture of such trends relies heavily on the continuity of the long-term monitoring program.*

Keywords: Microplankton Variability, Environmental Forcing, Nutrients Ratio

Introduction

The effects of global climate changes on West Antarctic Peninsula (WAP) have received special attention during last decade (e.g. Marshall *et al.*, 2002; Delille, 2004; Moline *et al.*, 2004; Montes-Hugo *et al.*, 2009). In this context, a monitoring program to study the planktonic biodiversity in shallow waters (<30m) at Admiralty Bay was implemented in 2002 by PROANTAR (Brazilian Antarctic Program) aiming to study the effects of environmental impacts (natural and anthropogenic) on the microplanktonic community structure, through the analysis of long-term time series.

These activities continued up to 2011. During this period four surveys were conducted in the area, with samplings in both early and late austral summer (Tenenbaum *et al.*, 2011a).

Recent studies show that in Admiralty Bay, picoplankton and ultraplankton are the dominant groups, followed by microplankton diatoms. Between 1990 and 2000, several studies indicate a decline in the relative contribution of diatoms to the total plankton (Kopczynska, 2008), when compared to communities in the continental shelf region.

These observations triggered implementations in the monitoring from 2009 onwards to include the analysis of size-fractionated pigments by spectrofluorometry (Tenório *et al.*, 2011) and the estimates of cell density and biovolume for ultraplankton by epifluorescence microscopy, as well as a higher sampling frequency (Tenenbaum *et al.*, 2011a). Additionally, the composition of microphytobenthos species has been carried out to study the effects of environmental changes on this community in the nearshore Antarctic ecosystem (Tenenbaum *et al.*, 2011b). The present study describes changes in plankton community structure at Admiralty Bay between two consecutive austral summers, 2009/2010 and 2010/2011.

Materials and Methods

Study area and sampling

Admiralty Bay (62° 03'–12'S, 58° 18'–38'W), located at King George Island, is a deep fjord-like embayment with 500 m maximum depth at its centre (Rakusa-Suszczewski *et al.*, 1993). The waters from the bay mix with the deep oceanic waters from Bellingshausen and Weddell Seas at its southern opening, which connects to the Bransfield Strait (Rakusa-Suszczewski 1980). The maximum depth varies between 60 m along the shores and 500 m in the centre of the bay. Deep currents generated by tides, frequent upwellings, vertical mixing of the entire water column and current velocities of 30–100 cm s⁻¹ in the 0–100 m surface stratum are characteristic of the bay (Rakusa-Suszczewski *et al.*, 1993).

The analysis of microplankton community composition and chlorophyll concentration measurements were performed on aliquots of 5-L samples collected with Niskin bottles at the surface, middle water column and near the bottom ($\approx$ 30m) at five sites in early (ES) and in late (LS) summer on 2009/2010 and 2010/2011 (n= 180 samples) (Tenório *et al.*, 2011). Temperature was measured *in situ* while salinity and nutrients analyses are present on Cascaes *et al.* (2012).

Fixation and preparation of samples

For microplankton ($>10\ \mu\text{m}$), 1 L aliquots were fixed with buffered formaldehyde (2% f.c.) and kept in the dark immediately after sampling. In the laboratory, samples

were analysed using the settling technique (Utermöhl, 1958) in an Olympus IX70^{*} inverted microscope with 400x magnification. For total pigments analyses, 0.5–2L aliquots were filtered onto Whatman[®] GF/F discs for. The filters were folded, placed into 1.2 mL cryotubes and immediately quick-frozen in liquid nitrogen (-196°C) and stored at -80°C . Concentrations of chlorophyll *a* (Chl.*a*) were assessed using a modified version of Neveux & Lantoiné's (1993) method, as described in Tenório *et al.* (2011).

In order to normalize distributions and eliminate zero values, the biological data was transformed using log₁₀ (x+1). Pearson's correlation factor was also calculated.

Results

During the study period, salinity at Admiralty Bay showed low variability, both spatial and temporally, with mean values varying between 34.1 and 34.2 (Table 1). On the other hand, water temperature presented a high temporal variability, both during the summer period and in between years. Average water temperature during 2010/2011 summer was higher than those registered during 2009/2010, both at ES and LS periods (Table 1, Figure 2).

Concentrations of dissolved inorganic nutrients were high throughout this study. Nitrate ($21.7 \pm 3.1\ \mu\text{M}$) and silicate ($71.1 \pm 10.2\ \mu\text{M}$) concentrations were similar in ES and LS for the 2009/2010 survey, whereas in 2010/2011 ES these values were higher than LS (Table 1). Phosphate concentrations ($\sim 1.9 \pm 0.4\ \mu\text{M}$) showed similar values for 2009/2010 ES and 2010/2011 LS.

The two first factors of the principal component analysis explained $\sim 70\%$ of variability in the data, discriminating four conditions associated to environmental variables and biomass, density and composition of microplankton community (Figures 2 and 3): 1- Low temperature, low N:P, medium Si:N, low Chl.*a*, low microplankton density, dominance of diatoms (ES XXVIII); 2- Medium temperature, low N:P, low Si:N, low Chl.*a*, low density, co-dominance of diatoms and autotrophic dinoflagellates (2009/2010 LS); 3- Medium temperature, high N:P, high Si:N, medium Chl.*a*, medium density, dominance of diatoms (2010/2011 ES); 4- High temperature, low N:P, high Si:N, high Chl.*a*, high density, dominance of diatoms (2010/2011 LS).

Table 1. Physical and chemical variables and Chl.a for each sampling period at Admiralty Bay (ES – Early Summer; LS – Late Summer). Average $\pm$ standard deviation (minimum – maximum)

2009/2010		Variables	2010/2011	
ES	LS		ES	LS
-0.18 ± 0.08 (-0.38 – 0.03)	0.85 ± 0.22 (0.43 – 1.13)	Temperature ($^{\circ}\text{C}$)	0.51 ± 0.26 (0.02 – 0.87)	1.62 ± 0.14 (1.39 – 1.92)
34.2 ± 0.1 (34.1 – 34.4)	34.1 ± 0.2 (33.6 – 34.3)	Salinity	34.2 ± 0.1 (33.7 – 34.4)	34.1 ± 0.2 (33.4 – 34.3)
14.8 ± 2.4 (7.5 – 17.8)	16.5 ± 2.4 (9.6 – 21.3)	NO ₂ +NO ₃ (μM)	21.7 ± 3.1 (14.0 – 26.7)	12.1 ± 3.7 (5.0 – 18.8)
1.9 ± 0.4 (1.3 – 2.8)	1.7 ± 0.6 (0.9 – 3.3)	PO ₄ (μM)	1.5 ± 0.4 (0.6 – 2.4)	1.8 ± 0.3 (1.4 – 2.9)
41.6 ± 1.0 (38.7 – 42.9)	41.2 ± 1.0 (38.1 – 42.3)	SiO ₄ (μM)	71.1 ± 10.2 (50.3 – 87.6)	37.8 ± 8.4 (19.6 – 56.6)
8.1 ± 2.0 (4.3 – 11.7)	10.4 ± 2.9 (5.6 – 17.6)	N:P	15.9 ± 5.0 (9.5 – 31.9)	6.9 ± 2.3 (2.8 – 13.3)
2.92 ± 0.79 (2.37 – 5.65)	2.57 ± 0.46 (1.95 – 4.25)	SiO ₄ :NO _x	3.37 ± 0.85 (2.03 – 6.10)	3.35 ± 1.06 (1.96 – 6.77)
0.38 ± 0.04 (0.31 – 0.45)	0.53 ± 0.25 (0.18 – 0.92)	Chl.a ($\mu\text{g. L}^{-1}$)	0.82 ± 0.61 (0.42 – 3.72)	2.92 ± 1.70 (0.40 – 6.11)

Figure 1. Principal Component Analysis with physical, chemical and microplanktonic variables with sampling sites means for different periods at Admiralty Bay (ES – Early Summer; LS – Late Summer).

Figure 2. Relationship between N:P ratio vs Temperature (a) and Silicate:Nitrate vs Temperature (b) scatter plots and microplankton biomass (diameter of sphere) and main groups composition (DIAT – diatom; DINO-AUT – autotrophic dinoflagellates; DINO-HET – heterotrophic dinoflagellates) for each sampling period at Admiralty Bay (ES – Early Summer; LS – Late Summer).

Discussion

Microplankton communities in coastal waters of the Western Antarctic Peninsula have become the focus of interest due to the possible effects that global climate changes may have on them. Variation in both atmospheric and water temperature could have dramatic effects to the whole food web, though e.g. melting of once-perennial sea ice and glaciers retreat (Turner *et al.*, 2005), as well as ice mesh increasing. In the short term (monthly-interannual scale) and during spring and summer, variations in latitudinal gradients in phytoplankton biomass as a function of time have been associated with sea ice timing and extent (Garibotti *et al.*, 2003). Our results demonstrate that Admiralty Bay experiments large water temperature changes both in monthly and interannual scales. The 2010/2011 summer registered positive water temperatures during the entire survey, being higher than those observed during the 2009/2010 survey that could affect ice-mesh processes, explaining the high nitrate and silicate concentrations at early 2010/2011 summer. Although nitrate was always at relatively high concentrations, N:P ratios suggested N-limitation for diatoms (16:1, N:P, Redfield, 1958) except for 2010/2011 ES. On the other hand, Si:N ratio higher than 1:1 would promote diatom growth (Brzezinski, 1985). Analyzing the four scenarios proposed in our studied we conclude that:

- 2009/2010 ES; diatom growth was promoted by high Si:N, but inhibited by low N:P and low temperature,
- 2009/2010 LS; diatom growth was inhibited by low N:P and low Si:N. High temperature and low N:P promoted dinoflagellates growth, due to their low optimum N:P ratios compared to diatoms, some dinoflagellate species may be selected at low N:P ratios (Hodgkiss & Ho, 1997),
- 2010/2011 ES; diatom growth was promoted by high N:P, high Si:N and high temperature,
- 2010/2011 LS; blooms of chain-forming diatoms (e.g. *Thalassiosira* spp.), favoured by high Si:N and high temperature, could explain the drastic reduction both in nitrate and silicate.

The dominance of diatoms over dinoflagellates in early summer 2010 is a characteristic of the microplankton community in the Admiralty Bay (Lange *et al.*, 2007; Kopczynska, 2008). Microplankton cellular densities and chlorophyll biomass observed during 2010/2011 were low when compared to those registered for Admiralty Bay during the 1970's, 1980's and 1990's, when densities of 10^5 cells L^{-1} were usually registered (*i.e.* Kopczynska, 2008). However, average cell densities in this study were six times higher than those observed by Lange *et al.* (2007) during the austral summer 2002/2003.

Conclusion

The microplankton community of Admiralty Bay presented a high variability during the studied period that was clearly dictated by environmental factors. The two-years study led to the identification of four scenarios dependent on water temperature, dissolved inorganic nutrients concentrations and ratios, which promoted different microplankton community responses, both in biomass, density and composition. The time window covered by this study gives us only a glimpse of the direction of long term changes that the Antarctic environment might be experiencing. A more complete picture of such trends relies heavily on the continuity of the long-term monitoring program.

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