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Seasonal characteristics of size-fractionated phytoplankton community and fate of photosynthesized carbon in a sub-Antarctic area (Straits of Magellan)

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ABSTRACT

Phytoplankton community size drives the rates of biogenic carbon and the overall structure and dynamics of the marine pelagic food web. The Straits of Magellan, an inland passage between the Pacific and Atlantic Oceans, can be separated into three main sub-basins: the western-Pacific, the V-shaped central zone, and the eastern-Atlantic. To provide insights into the food structure of the phytoplankton community, size-fractionated chlorophyll a concentration and primary production rates were measured across the three sectors of the Magellan Straits in four periods between 1989 and 1995 in the Straits. Phytoplanktonic biomass and production ratios provided ecological insights into the food web structure, including the relevance of grazing in its largest fraction.
The micro-phytoplanktonic fraction (>10 μm) in the Pacific sub-basin is significantly less abundant than in the Central and Atlantic ones. Conversely, the lowest abundance of the pico-fraction (<2.0 μm) is encountered in the Atlantic sub-basin. The observed patterns agree with the diffusion of smaller-size fractions from the western towards the easternmost sector of the Straits, and suggest that the largest phytoplankton tend to accumulate in the inner stretch of the Straits, being constrained by a clockwise gyre generated by tidal phases or partially spilling out into the Atlantic sector. The most active grazing activities occur in the Central sub-basin during the spring bloom and appear even stronger in summer.
Our results pinpoint also that the basic levels of the planktonic food web rely on the nanophytoplankton (10–2 μm) fraction, which is the main contributor to the continuum multivorous food web. When external energy (e.g. nutrient pulses from land freshwater and water mixing) enters the system, the structure of the plankton in the Straits shifts towards the herbivorous food web and is characterized by the presence of large-size diatoms. This dynamics keeps the system in a persistent mesotrophic state, featuring a lower trophic status than the Antarctic ones but much higher than that of oligotrophic temperate areas.

1. Introduction

Species composition and size structure of the phytoplankton community determine the overall structure and dynamics of the marine pelagic food web and control the rates of biological processes and the interactions among plankton organisms (Armstrong, 1994; Tang, 1995). Furthermore phytoplankton size composition provides insights about the production and fate of the biogenic carbon and drives the processes of export or recycling in the photic system (Legendre and Le Fevre, 1989; Legendre and Rassoulzadegan, 1996; Tremblay and Legendre, 1994).

Usually, communities dominated by large-sized phytoplankton have high rates of biogenic matter export to higher trophic level. Conversely, communities dominated by small phytoplankton mainly function through the microbial food web and are characterized by the continuous recycling of the small amounts of recently-photosynthesized organic matter. In-between these two edges, the trophic continuum includes the "multivorous" and "microbial" pathways. In the multivorous food web, herbivorous and microbial trophic components have an active role, whereas the microbial food web includes microbial loop and nano-phytoplankton so that it can export carbon (Legendre and Rassoulzadegan, 1995; Mosseau et al., 2001; Rassoulzadegan, 1993). Both these food webs express different ecological and biogeochemical significances linked to the biogenic carbon flux.

From an ecosystem point of view, in polar environments the factors modulating the size structure of the phytoplankton community include either bottom–up and top–down mechanisms. Bottom–up factors (e.g. light climate, water column dynamics, micro- and macronutrients) mainly control the growth of "large" phytoplankton cells

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(Torres et al., 2011), whereas top-down mechanisms (e.g., micro-zooplankton grazing) preferentially control communities dominated by "small" phytoplankton cells (Smith and Lancelot, 2004). The two types of plankton communities have been described at all latitudes around the world including both Antarctic and Sub-Antarctic regions. The classical view about the functioning of the polar food web structure indicates the predominance of large diatoms (>20 μm) linked to the classical food web leading to krill (Guillard and Kilham, 1977; Hasle, 1969). However, recent studies suggested that an alternate food web based on microbial components coexists in parallel with the classic food chain. The microbial carbon pathway taking place at the lower trophic level includes pico- and nano-sized primary and secondary producers (Fiala et al., 1998).

The objective of the present work is to re-process the first data on the size structure and function of the phytoplankton community in the Straits of Magellan (Magazzù et al., 1991) by adding new information collected in the last cruise of the Italian National Research Programme in Antarctica (1989–1995). A specific aim of this study is to further explore the role of phytoplankton size-fractions (pico-, nano-, and micro-fractions) in channeling their production through the planktonic food web (recycle/accumulation vs. export) in different sectors of the Straits and different time. The general objective is to support the formulation of a functioning scheme of the first trophic level of this sub-Antarctic planktonic food web, where different carbon pathways were recognized and reported in previous studies (Iriarte et al., 1993; Magazzù et al., 1996; Saggiomo et al., 1994, 2011; Vanucci and Mangoni, 1999).

1.1. Study area

The Straits of Magellan (Fig. 1) is a fjord system located within the latitudinal range of the West Wind Drift (Humboldt current), 8° north of the Polar Front, influenced by the sub-Antarctic adjacent waters. It is a narrow passage about 570-km-long that joins the Pacific and Atlantic Oceans at the southernmost edge of South America. On the basis of the gross bathy-morphological features, the Straits can be divided into three main hydrographical sub-basins (Panella et al., 1991). The western and deeper Pacific sub-basin extends from the Pacific entrance (Cabo Deseado) to the sill of Carlos III Island, the V-shaped Central sub-basin up to Paso Ancho and the eastern and shallow Atlantic sub-basin from the Angosturas to the Atlantic Ocean (Punta Dungeness). The hydrographical features of this Sub Antarctic inland passage can be summarized as follows: i) the western sector is influenced by subsurface Pacific waters which intrude in the layer 100–150 m below the colder run-off waters of the Andean glaciers; ii) east of the Carlos III sill, Pacific waters entering from southern openings (through Seno Magdalena) influence the central sector in the layer 100–400 m and limit the weak cyclonic circulation in Paso Ancho basin promoting a stratified and stable water column which receives fresh inputs from Fuegian mainland through Bahia Inutil; iii) the Patagonian sector is dominated by strong tides forced through the Atlantic opening, which induce a turbulent and mixed environment (Antezana, 1999a, 1999b; Artegiani, 1991; Budillon et al., 1996; Spezie et al., 1997). Morphology, a dominant feature of the Strait of Magellan, induces a spatial modulation of forcings such as run-off and oceanic inputs to the system that, in turn, influence the local trophic conditions (Carrada et al., 1994) so that areas of relatively low and high phytoplankton biomass and primary production alternate across the Straits (Saggiomo et al., 1994).

2. Materials and methods

2.1. The dataset

In the framework of the Italian National Research Programme in Antarctica (PNRA) several multidisciplinary activities were carried out in the Straits of Magellan during four cruises from November 1989 to April 1995 (Anonymous, 1991a, 1991b; Faranda and Guglielmo, 1993; Faranda et al., 1996; Magazzù, 1991). Among the fieldwork products we considered all the available oceanographic and chemico-physical data and the measurements of size-fractionated phytoplankton biomass and activity in the upper 50 meter layer along the Straits of Magellan, from the Pacific to the Atlantic Oceans (Table 1).

The data were collected in the Straits during four oceanographic cruises carried out in November 1989 on board R/V Explora (Exp.89 cruise, austral spring), February–March 1991 on board R/V Cariboo (Car.91 cruise, austral summer), March–April 1991 on board R/V

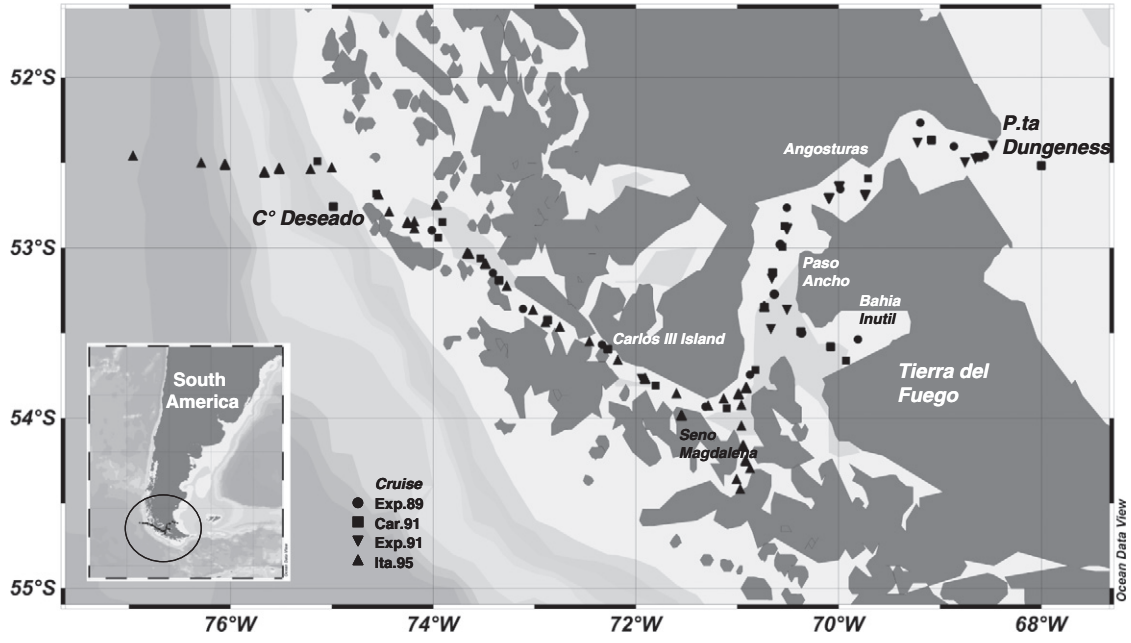

Fig. 1. The positions of the sampling stations in the Straits of Magellan during the cruises of the Italian National Programme of Research in Antarctica (1989–1995).