A trait-based characterization of phytoplankton communities in contrasting environmental regions of the Atlantic Ocean

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Introduction For decades ecologists have been trying to understand how the phytoplankton patterns of community structure are associated to the environmental conditions, with a particular focus on the causes and consequences of natural variations. One of the approaches adopted in this quest is based on observations of key characteristics of organisms, populations or communities. These key characteristics are also called traits McGill2006, Violle2007.

Trait-based ecology aims at developing an understanding and a better predictability of natural communities by linking traits that influence organism performances and fitness with prevailing environmental conditions McGill2006. For example, recent investigations suggest that changes in mean trait and trait variance are invariable to different spatial scales, thus stressing the importance of the environmental conditions on trait variation and implying that the within-species and the interspecific variations on natural communities do not add more variation to the trait Messier2010.

Phytoplankton organisms are ideal systems for trait-based approaches. They are relatively simple with well defined ecological niches which are determined by the physical environment, the resource allocation strategies, and the interspecific relationships Litchman2007. They have various morphological, physiological, behavioral and life history traits and trade-offs. Among all the known phytoplankton traits, cell-size is probably the best characterizing property of phytoplankton communities because many ecophysiological processes such as nutrient and light utilization and resistance to grazing, are significantly correlated with cell size Litchman2008,Litchman2010. In vivo and in situ observations of a variety of traits are constantly measured due to the global importance of phytoplankton as primary producer, influencing trophic webs and biogeochemical cycles Falkowski1998.

Almost every year, since 1995, two scientific cruises have been crossing the Atlantic ocean from Plymouth (UK) to South America or South Africa, with observations including size fractionated chlorophyll-a, nitrate, phosphate and silicate concentrations, temperature and zooplankton abundances. These cruises are part of the Atlantic Meridional Transect Programme. Given the spatial extent of the transect, which crosses a range of ecosystems from sub-polar to tropical and from euphotic shelf seas and upwelling systems to oligotrophic mid-ocean gyres, the dataset is ideal for studying phytoplankton community structure and the driving processes of size composition at an ocean basin scale. Previous analyses attempted a description of the occurrences of the different size fractions Maranon2001 without considering a direct influence of the prevailing environmental conditions. A more comprehensive analysis that integrates all the different AMT data with the available phytoplankton community size-fractions is, to our knowledge, still lacking. Therefore, our work intends to uncover the mechanisms shaping the different phytoplankton community structures in regions of contrasting environmental conditions (that is: regions with different nutrient regimes and grazing pressures).

We broaden previous analyses by considering a larger selection of data than any previous study. More specifically, we integrate phytoplankton size-fractions with temperature, various nutrient concentrations, and zooplankton abundances in the attempt of disentangling the relative contribution of bottom-up and top-down processes in shaping phytoplankton size structure.

A first step in our analyses was to pre-structure the selected AMT dataset according to a well established ecological classification of marine data into ocean provinces characterised by different environmental conditions Longhurst2006. In the second step, we propose a new classification using the available data of nutrient regimes and grazing, and compare our results with those of Longhurst2006. In the last step, we relate the environmental differences and the relative contributions of bottom-up versus top-down processes to the different community size structures in order to highlight the emergent patterns of community compositions and structures at the ocean basin scale.

Methods

We composed a dataset by selecting a number of observed variables from the Atlantic Meridional Transect (AMT) Program (www.amt-uk.org). The resulting dataset comprises mixed-layer depth values of size fractionated chlorophyll-a, nitrate, phosphate and silicate concentrations, temperature, and zooplankton abundances (as a relative indication of grazing pressure). As mixed layer depth we considered that depth at which a variation of 0.5 °C in temperature and of 0.125 in density is observed with respect to surface value (i.e. first value at 5-10 m depth). We obtained a dataset of 410 samples from a total of 9 AMT cruises (from AMT2 to AMT6, AMT10, AMT11, AMT13, AMT14). These cruises took place in April-May or September-October in the years 1996 (AMT2 and AMT3), 1997 (AMT4 and AMT5), 1998 (AMT6), 2000 (AMT10 -AMT11), and 2003 (AMT13 and AMT14).

The phytoplankton size fractions available were in the range of picoplankton (0.2-2 μm), nanoplankton (2 -20 μm), and microplankon (>20 μm). AMT13 and AMT14 measured four size classes (0.2-2, 2-5 5-10, >10 μm). Thus, to be consistent with the three plankton size ranges, we considered the 2-5 and 5-10 μm size classes as part of the nanoplankton class and the >10 μm class as part of the microplankton class. We checked for the results with and without these data and there was no appreciable difference in the resulting patterns. The three size fractions were normalized, based on the proportion of each size fraction to the total Chl-a concentration.

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