ELSEVIER

Deep-Sea Research II 53 (2006) 1593–1610

DEEP-SEA RESEARCH
PART II

www.elsevier.com/locate/dsr2

Phytoplankton carbon fixation, chlorophyll-biomass and diagnostic pigments in the Atlantic Ocean

Alex J. Poulton[a,*], Patrick M. Holligan[a], Anna Hickman[a], Young-Nam Kim[a], Tim R. Adey[a], Mark C. Stinchcombe[a], Claire Holeton[b], Sarah Root[a], E. Malcolm S. Woodward[c]

[a]*National Oceanography Centre, University of Southampton, Southampton SO14 3ZN, UK*
[b]*Department of Plant Ecology, Uppsala University, Uppsala SE-752 36, Sweden*
[c]*Plymouth Marine Laboratory, Plymouth PL1 3DH, UK*

Received 26 August 2005; received in revised form 15 December 2005; accepted 15 May 2006
Available online 14 August 2006

Abstract

We have made daily measurements of phytoplankton pigments, size-fractionated (<2 and >2-μm) carbon fixation and chlorophyll-*a* concentration during four Atlantic Meridional Transect (AMT) cruises in 2003–04. Surface rates of carbon fixation ranged from <0.2-mmol C m^{-3} d^{-1} in the subtropical gyres to 0.2–0.5-mmol C m^{-3} d^{-1} in the tropical equatorial Atlantic. Significant intercruise variability was restricted to the subtropical gyres, with higher chlorophyll-*a* concentrations and carbon fixation in the subsurface chlorophyll maximum during spring in either hemisphere. In surface waters, although picoplankton (<2-μm) represented the dominant fraction in terms of both carbon fixation (50–70%) and chlorophyll-*a* (80–90%), nanoplankton (>2-μm) contributions to total carbon fixation (30–50%) were higher than to total chlorophyll-*a* (10–20%). However, in the subsurface chlorophyll maximum picoplankton dominated both carbon fixation (70–90%) and chlorophyll-*a* (70–90%). Thus, in surface waters chlorophyll-normalised carbon fixation was 2–3 times higher for nanoplankton and differences in picoplankton and nanoplankton carbon to chlorophyll-*a* ratios may lead to either higher or similar growth rates. These low chlorophyll-normalised carbon fixation rates for picoplankton may also reflect losses of fixed carbon (cell leakage or respiration), decreases in photosynthetic efficiency, grazing losses during the incubations, or some combination of all these. Comparison of nitrate concentrations in the subsurface chlorophyll maximum with estimates of those required to support the observed rates of carbon fixation (assuming Redfield stoichiometry) indicate that primary production in the chlorophyll maximum may be light rather than nutrient limited.

Keywords: Phytoplankton; Carbon fixation; Picoplankton; Nanoplankton; Chlorophyll-*a*; Atlantic Meridional Transect

1. Introduction

The size structure and taxonomic composition of the phytoplankton community in the open ocean are important factors in regulating organic carbon export to the deep ocean (Azam et al., 1983; Tremblay and Legendre, 1994). Phytoplankton

*Corresponding author. Tel.: +44 2380592262; fax: +44 2380593564.
E-mail address: aljp@noc.soton.ac.uk (A.J. Poulton).

0967-0645/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.dsr2.2006.05.007

may be classified by cell size (e.g. Sieburth, 1979) to include small picoplankton (0.2–2 μm in diameter; e.g. prochlorophytes, *Synechococcus* spp., small eukaryotes), medium-sized nanoplankton (2–20 μm; e.g. prymnesiophytes, pelagophytes, small diatoms and dinoflagellates), and larger microplankton (>20–200 μm; e.g. diatoms and dinoflagellates). Factors that influence the composition and dynamics of the phytoplankton community (nutrient and light availability, turbulence and predation) vary in time and space, leading to significant variability in phytoplankton diversity and growth rates. Typically, the upper ocean is regarded as composed of an upper light-rich and nutrient-limited surface layer, and a deep light-limited and nutrient-rich layer (e.g. Dugdale, 1967).

Within the Atlantic Ocean the main ecological regimes include regions with relatively high chlorophyll-*a* at high latitudes (>40°; temperate zones) and in the equatorial Atlantic (10°S—20°N) and coastal upwelling, and regions with relatively low chlorophyll-*a* around the central subtropical gyres (10–40°) of the northern and southern hemispheres. Despite low biomass and primary production, which characterise the central subtropical gyres (Karl, 1999), their large spatial extent means that they account for a significant fraction (30–50%) of global oceanic primary productivity and export production (Karl et al., 1996). Although picoplankton represent the dominant component of the phytoplankton in terms of primary productivity, chlorophyll-*a* and cell densities within nutrient poor subtropical waters (Marañón et al., 2000; Zubkov et al., 1998, 2000), a significant proportion of the primary productivity can be attributed to the nano- and microphytoplankton (Marañón et al., 2000, 2001; Fernández et al., 2003).

In the equatorial Atlantic, elevated phytoplankton biomass and primary productivity are found throughout most of the year (Pérez et al., 2005a, b). The community remains dominated by picoplankton (Herbland et al, 1987; Zubkov et al., 1998, 2000; Pérez et al., 2005b), although *Synechococcus* spp. and picoeukaryotes become relatively abundant (Zubkov et al., 1998, 2000), and compared to the subtropical gyres, increases in nanoflagellates (Tarran et al., 2006) and pigments diagnostic of diatoms and dinoflagellates (Gibb et al., 2000; Barlow et al., 2002, 2004) are also observed. Primary productivity measurements from the equatorial Atlantic show a similar size structure to those from the central subtropical gyres with a dominance of picoplankton and greater nano- and microplankton contributions to primary production than to total chlorophyll-*a* (Marañón et al., 2000, 2001; Pérez et al., 2005b). High primary productivity and chlorophyll-*a* concentrations are also found in association with areas of coastal upwelling, although in this case there are significant changes in the size structure of the community, with increases in the abundance of diatoms and dinoflagellates (Gibb et al., 2000; Barlow et al., 2002, 2004) and nano- and microplankton dominate both production and biomass (Marañón et al., 2000, 2001; Tarran et al., 2006).

The main objective of this study is to investigate the spatial and temporal variability of phytoplankton community composition and carbon fixation in tropical equatorial and subtropical central gyre waters of the Atlantic Ocean. To address this objective we have made depth-resolved measurements of daily particulate carbon fixation, chlorophyll-*a* concentration and phytoplankton diagnostic pigments (DP) during four basinscale cruises in the Atlantic Ocean (2003–04) as part of the recent phase of the Atlantic Meridional Transect programme (see http://www.amt-uk.org); 'gyre'-focused cruises AMT-12 (May, 2003) and AMT-14 (May, 2004), and the 'upwelling'-focused cruises AMT-13 (September, 2003) and AMT-15 (September, 2004) (Fig. 1). Measurements of carbon fixation and chlorophyll-*a* were size-fractionated into two fractions: 0.2–2 μm, picoplankton, and >2 μm, nanoplankton and microplankton (herein termed nanoplankton). Rates of particulate carbon fixation were determined from dawn to dusk incubations and dissolved organic production was not measured. As spatial and temporal variability of respiration rates (photorespiration, dark respiration) will determine the balance between daily rates of carbon fixation and primary productivity (Falkowski and Raven, 1997), and are outside the scope of this paper, we retain the rates of carbon fixation as a proxy of daily phytoplankton community production and growth.

2. Methods

2.1. Sampling

Water samples were collected during daily predawn (0200–0400 h, local time) and mid-morning (1100–1200 h) deployments of a 24×20 l SeaBird CTD rosette sampler. Sampling depths were determined by in situ fluorescence (WetLabs