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Phytoplankton pigment and absorption characteristics along meridional transects in the Atlantic Ocean

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Abstract

Pigment patterns and associated absorption properties of phytoplankton were investigated in the euphotic zone along two meridional transects in the Atlantic Ocean, between the UK and the Falkland Islands, and between South Africa and the UK. Total chlorophyll *a* (TChla = MVChla + DVChla + chlorophyllide *a*) concentrations and the biomarker pigments for diatoms (fucoxanthin), nanoflagellates and cyanobacteria (zeaxanthin) appeared to have similar distribution patterns in the spring and in the autumn in the temperate NE Atlantic and the northern oligotrophic gyre. Divinyl chlorophyll *a* levels (prochlorophytes) were greater in spring at the deep chlorophyll maximum in the oligotrophic gyre, however. Marked seasonal differences were observed in the NW African upwelling region. TChla concentrations were twice as high in the upper mixed layer in the spring, with the community dominated by diatoms and prymnesiophytes (19′-hexanoyloxyfucoxanthin). A layered structure was prevalent in the autumn where cyanobacteria, diatoms and prymnesiophytes were located in the upper water column and diatoms and mixed nanoflagellates at the sub-surface maximum. In the South Atlantic, the Benguela upwelling ecosystem and the Brazil-Falklands Current Confluence Zone (BFCCZ) were the most productive regions with the TChla levels being twice as high in the Benguela. Diatoms dominated the Benguela system, while nanoflagellates were the most ubiquitous group in the BFCCZ. Pigment concentrations were greater along the eastern boundary of the southern oligotrophic gyre and distributed at shallower depths. Deep chlorophyll maxima were a feature of the western boundary oligotrophic waters, and cyanobacteria tended to dominate the upper water column along both transects with a mixed group of nanoflagellates at the chlorophyll maximum.

Absorption coefficients were estimated from spectra reconstructed from pigment data. Although absorption was greater in the productive areas, the TChla-specific coefficients were higher in oligotrophic regions. In communities that were dominated by diatoms or nanoflagellates, pigment absorption was generally uniform with depth and attenuating irradiance, with TChla being the major absorbing pigment at 440 nm and photosynthetic carotenoids (PSC) at 490 nm. Absorption by chlorophyll *c* and photoprotective carotenoids (PPC) was much lower. Populations where cyanobacteria were prevalent were characterized by high PPC absorption, particularly at 490 nm, throughout most of the euphotic zone. The data suggested that the effect of pigments on the variability of phytoplankton absorption was due primarily to the variations in absorption by PPC.

1. Introduction

Spatially extensive investigations have been coordinated within the UK Atlantic Meridional Transect (AMT) programme with the purpose of improving our knowledge of biogeochemical processes, ecosystem dynamics and food webs across basin scales in the Atlantic Ocean (Aiken et al., 2000). One of the goals of the programme has been to examine and characterize the properties of biogeochemical provinces (Longhurst et al., 1995), and an objective method was developed to determine the boundaries of physical provinces (Hooker et al., 2000). Another objective has been to conduct ground-truthing measurements of optical and pigment parameters for the validation and calibration of SeaWiFS ocean colour data (Hooker and McClain, 2000). In this regard, the surface distribution pattern of pigments for transects between the UK and the Falkland Islands was discussed by Gibb et al. (2000), and Barlow et al. (in press) have examined the bio-optical properties of surface pigments in relation to ocean colour data of absorption and back scattering for a transect between South Africa and the UK. Observations of the variability in the vertical distribution of phytoplankton pigments and associated absorption properties across Atlantic basins, however, have not yet been reported.

Total chlorophyll *a* (TChla), defined as the sum of MVChla, DVChla and chlorophyllide *a*, is used as a surrogate marker for the abundance of phytoplankton in the oceans, but other accessory pigments that can be identified and quantified by liquid chromatography (Jeffrey et al., 1997) provide chemotaxonomic information on the range of phytoplankton groups that make up the community structure in the Atlantic (Barlow et al., 1993, in press; Bidigare et al., 1990a; Gibb et al., 2000). The major role of chlorophyll *a* is to absorb light for photosynthesis, but there is also a range of pigments, such as, chlorophylls *b* and *c* plus a variety of carotenoids, that have a significant function in extending the light-harvesting spectrum in the phytoplankton, thus ensuring optimal absorption efficiencies (Kirk, 1994). Other carotenoids, however, serve to protect microalgal cells against the effects of high irradiances, which may damage the photosynthetic apparatus, and these pigments may be termed photoprotective carotenoids (PPC) (Kirk, 1994).

4. Discussion

4.1. Phytoplankton communities

The AMT cruises were essentially confined to investigating only the autumn and spring seasons in the Atlantic because of the logistical programme of the research vessel (Aiken et al., 2000). During AMT-3 (September–October 1996), it was autumn in the North Atlantic and spring in the south; for AMT-6 (May–June 1998), it was autumn in the South Atlantic and spring in the north. Thus, for the NE Atlantic, the two seasons can be compared because the cruise tracks were similar (Fig. 1). The cruise tracks in the southern hemisphere were on opposite sides of the South Atlantic basin, and therefore, the communities along the eastern and western boundaries could be compared, even though the observations were made in different seasons.

The phytoplankton in the temperate NE Atlantic and the northern oligotrophic gyre appeared to have similar characteristics for both the autumn and spring seasons. TChla levels were similar (Figs. 2 and 3) as well as the distribution pattern for diatoms (Fuc) and nanoflagellates (Hex + But + All + Chlb). Dinoflagellates (Per) were detected only in the upper water column on the European shelf during autumn (Fig. 2), but were virtually undetectable in the spring (Fig. 3). The cyanobacterial pattern (Zea) also appeared to be similar for both seasons, although the concentrations of divinyl chlorophyll *a* (prochlorophytes) were greater in the spring (AMT-6) at the deep chlorophyll maxima in the oligotrophic gyre (Figs. 2 and 3). The selected vertical profiles confirmed the observations of the contoured data, but provided more detail on subtle differences. The profiles for 49.68°N and 48.45°N indicated a more diverse nanoflagellate community in the temperate NE Atlantic during autumn (AMT-3) compared to the spring (AMT-6), with chlorophyll *b* being significant in autumn but not in the spring (Figs. 4 and 7). At 29.49°N and 28.68°N, both communities displayed a layered structure, typical of oligotrophic communities, where cyanobacteria (Zea) and prymnesiophytes (Hex) dominated the upper 80–100 m, and a group of mixed flagellates were abundant at the chlorophyll maximum and below (Figs. 4 and 7). Chlorophyll *b* was most prominent at the deep maximum during both seasons, and this was due to the increased synthesis of divinyl chlorophyll *b* in prochlorophyte cells at depth to maximize their absorption of low intensity blue light (Fig. 7, 28.68°N).

These observations are consistent with other studies in the North Atlantic. Bidigare et al. (1990a) and Barlow et al. (1993) reported diatom dominance during spring bloom investigations that were conducted early in the season, followed by a succession to nanoflagellates when key nutrients declined. The temperate NE Atlantic in June 1998 corresponded to the end of bloom conditions, so nanoflagellates were the dominant organisms. The phytoplankton pattern in the northern oligotrophic region appears to be consistent during all seasons, because a similar layering structure of pigments has been demonstrated in North Atlantic oligotrophic waters by Claustre and Marty (1995), Babin et al. (1996), Lazzara et al. (1996) and Goericke (1998). Barlow et al. (in press) and Gibb et al. (2000) estimated the contribution of divinyl chlorophyll *a* to TChla in the northern gyre can be up to 50% in surface waters, indicating the importance of prochlorophytes. Divinyl chlorophyll *a* concentrations in this study were greater at the subsurface maximum than at the surface, but accounted for similar proportions at 37–53% for AMT-3 and 31–50% for AMT-6.