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Adaptation of phytoplankton communities to mesoscale eddies in the Mozambique Channel

R. Barlow [a,b], T. Lamont [b,c,*], T. Morris [a], H. Sessions [c], M. van den Berg [c]

[a] Bayworld Centre for Research & Education, PO Box 7296, Roggebaai 8012, Cape Town, South Africa
[b] Marine Research Institute, University of Cape Town, Private Bag X3, Rondebosch 7701, South Africa
[c] Oceans & Coasts Research, Department of Environmental Affairs, Private Bag X2, Rogge Bay 8012, South Africa

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ABSTRACT

An investigation of phytoplankton pigment and absorption characteristics was undertaken during three research cruises in the Mozambique Channel to elucidate community structure and examine the adaptation of populations to mesoscale features at the surface and the deep chlorophyll maximum (DCM). Total chlorophyll *a* concentration (TChla) at the surface was determined to be greater in cyclonic eddies than in anticyclones, while TChla in divergence and shelf zones were similar to cyclones, with frontal zones being slightly lower. TChla at the DCM was similar for all categories, although there was a tendency for anticyclones to have lower TChla. Prokaryotes were the most significant phytoplankton group at the surface, with small flagellates also being of secondary importance, while flagellates dominated at the DCM. A few shelf stations, and frontal and shelf stations close to the shelf, displayed high TChla and diatom domination, particularly at the DCM. Absorption properties and photopigment indices revealed that prokaryote dominated communities had high chlorophyll-specific absorption coefficients, a large range in the proportion of TChla within the total pigment pool and a high proportion of photoprotective carotenoids. Diatoms had low chlorophyll-specific absorption, a relatively high proportion of TChla, and elevated proportions of photosynthetic carotenoids and chlorophyll *c*. Flagellate dominated communities had intermediate chlorophyll-specific absorption, a lower proportion of TChla, elevated photosynthetic carotenoids and intermediate chlorophyll *c*.

1. Introduction

The Mozambique Channel between Madagascar and Mozambique is unique in that flow through the channel is dominated by a series of southward drifting anti-cyclonic eddies, rather than a continuous western boundary current (De Ruijter et al., 2002; Lutjeharms et al., 2000). The diameter of these eddies can be up to 300 km and they extend to the ocean floor, transporting large volumes of water through the channel at $15 \times 10^6\ m^3\ s^{-1}$. On average, they move about 4.5 km d^{-1}, but this can vary up to 6 km d^{-1}, although lower rates of 3–4 km d^{-1} have been observed between 18° and 21°S (Schouten et al., 2003). The trajectory of these eddies follows a path along the western part of the channel and they eventually emerge and are absorbed into the Agulhas Current to the south (De Ruijter et al., 2002). On this trajectory, eddies move past the Mozambican shelf, and the resulting interaction induces coastal waters to be swept offshore into mid-channel (Quartly and Srokosz, 2004). Some of the eddies that flow close to the coast may also become trapped, lee eddies, where poleward flow intensifies along the headland at 15°S, driving cyclonic lee eddies downstream at 17°S with diameters of 100 km (Lutjeharms, 2006). Nutrient rich deeper water is usually upwelled by these features, with a corresponding increase in phytoplankton biomass.

Although the physical oceanography of the Mozambique Channel has received considerable attention, studies of phytoplankton have been limited. Investigations during the International Indian Ocean Expedition of 1963–1964 indicated that primary production in the channel was quite variable, with rates of 0.26–0.5 g C $m^{-2}\ d^{-1}$ in mid-channel and 1–3 g C $m^{-2}\ d^{-1}$ on the Mozambique shelf in the vicinity of the Sofala Banks and the Delagoa Bight (Ryther et al., 1966). Biomass investigations of these shelf zones in the late 1970s indicated chlorophyll *a* concentrations varying from 0.06 to 1.26 mg m^{-3} at the surface (Mordasova, 1980), but no in situ estimates were reported for the offshore waters in mid-channel. A combined flow cytometry and satellite ocean colour investigation of surface waters along a transect in August 2001 showed chlorophyll *a* varying from 0.1 mg m^{-3} in mid-channel to 0.3 mg m^{-3} in the southwest closer to Mozambique and in the northeast near

* Corresponding author at: Oceans & Coasts Research, Department of Environmental Affairs, Private Bag X2, Rogge Bay 8012, Cape Town, South Africa.
E-mail addresses: rgb.barlow@gmail.com (R. Barlow), tarron.lamont@gmail.com (T. Lamont).

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Madagascar (Zubkov and Quartly, 2003). *Prochlorococcus* was found to be numerically dominant, followed by *Synechococcus* and then picoeukaryotes in lower abundance. Satellite climatology indicated a seasonal cycle in surface chlorophyll *a* in the Mozambique Channel, varying between 0.15 and 0.3 mg m^{-3}, with a winter maximum in July and a minimum in summer during December (Levy et al., 2007). A combined satellite and modelling study confirmed the winter maxima and summer minima, although a time series from 1998 to 2007 revealed considerable interannual variability in chlorophyll *a* levels and the months when the peaks occurred (Omta et al., 2009). Another satellite and modelling study revealed the influence of eddies on phytoplankton biomass, where the predominance of anticyclonic eddies in the channel resulted in below normal chlorophyll *a* levels, while chlorophyll *a* was enhanced when cyclonic eddies were dominant (Tew Kai and Marsac, 2009).

There is a limited understanding of the influence of mesoscale features on biological production in the Mozambique Channel, with ecosystem functions appearing to be constrained by the formation of eddies and their migration. Questions maybe asked concerning the levels of primary, secondary and tertiary production and biomass within anticyclonic and cyclonic eddies, and within the frontal zones between these eddies. It has been observed that top predators such as frigate birds and tuna feed preferentially in these frontal zones (Weirmerskirch et al., 2004; Tew Kai and Marsac, 2010). The interaction of eddies with the Mozambican shelf also has implications for the export of shelf waters with higher plankton biomass into the middle of the channel and its influence on the marine food web. In order to understand ecosystem functions in more detail, a regional research programme (MESOBIO) was initiated to conduct multidisciplinary investigations in the Mozambique Channel with a series of research cruises being staged during 2008–2011 (Ternon et al., 2014). Phytoplankton was an important component and the objective of this study was to use pigment and absorption data to

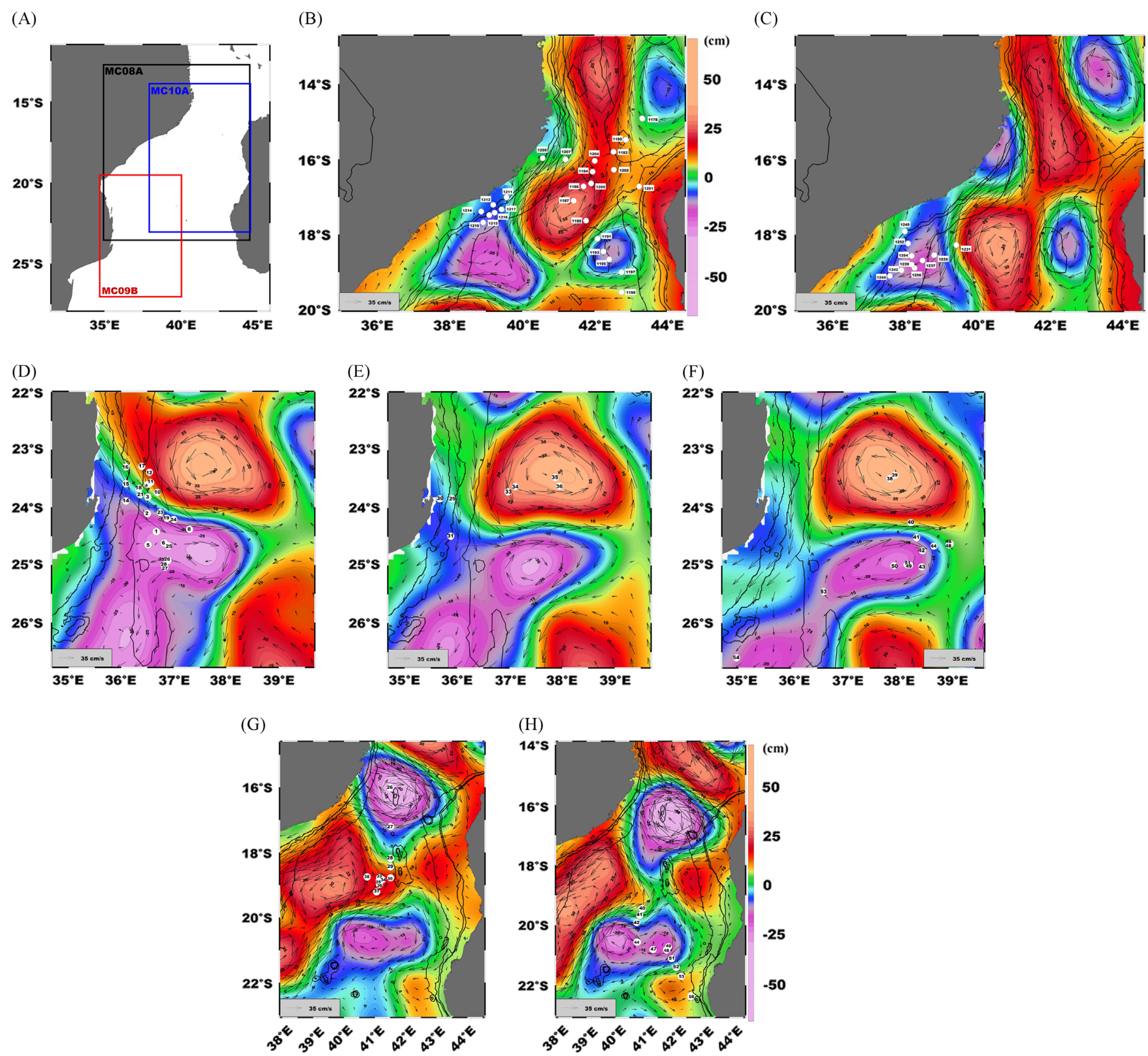

Fig. 1. Sampling stations for absorption and pigments in the Mozambique Channel overlaid on maps of sea surface height anomalies: (A) areas for cruises MC08A, MC09B and MC10A; (B, C) cruise MC08A; (D–F) cruise MC09B; (G, H) cruise MC10A. Scale bar indicates sea surface height anomalies on all maps.