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ORIGINAL PAPER

The influence of *Phaeocystis globosa* on microscale spatial patterns of chlorophyll *a* and bulk-phase seawater viscosity

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Abstract A two-dimensional microscale (5 cm resolution) sampler was used over the course of a phytoplankton spring bloom dominated by *Phaeocystis globosa* to investigate the structural properties of chlorophyll *a* and seawater excess viscosity distributions. The microscale distribution patterns of chlorophyll *a* and excess viscosity were never uniform nor random. Instead they exhibited different types and levels of aggregated spatial patterns that were related to the dynamics of the bloom. The chlorophyll *a* and seawater viscosity correlation patterns were also controlled by the dynamics of the bloom with positive and negative correlations before and after the formation of foam in the turbulent surf zone. The ecological relevance and implications of the observed patchiness and biologically induced increase in seawater viscosity are discussed and the combination of the enlarged colonial form and mucus secretion is suggested as a competitive advantage of *P. globosa* in highly turbulent environments where this species flourishes.

Keywords Eastern English Channel · Patchiness · *Phaeocystic globosa* · Plankton rheology · Turbulence

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Introduction

Plankton patchiness is widely acknowledged as a ubiquitous and key feature of marine ecosystems (Martin 2003). Many organisms have been shown to exploit patches of food (e.g., Tiselius 1992), and patch formation may be important in the foraging success of many marine invertebrates (Seuront et al. 2001) and vertebrates (Cartamil and Lowe 2004), as well as for the sexual encounters among individuals of relatively rare species (Buskey 1998). While the quantification of the spatial and temporal structure of phytoplankton distributions has for the most part focussed on empirical observations at scales greater

than 10 m to several kilometres (Martin 2003), there is a growing evidence for the existence of both vertical and horizontal phytoplankton patchiness at scales smaller than one metre (e.g., Dekshenieks et al. 2001). Because the analysis of large-scale patterns must integrate processes occurring at much smaller scales (Levin 1992), investigating the physical and biological dynamics controlling microscale plankton patchiness may be an absolute prerequisite to improve our understanding of the scales, intensities, durations and ecological relevance of these patterns.

The cosmopolitan genus *Phaeocystis* is a key organism in driving global geochemical cycles, climate regulation and fisheries yield (Schoemann et al. 2005), and has recently been suggested as a potential source of microscale phytoplankton patchiness (Seuront 2005). Of particular importance is the formation of large, gel-like colonies (from several mm to several cm; Verity and Medlin 2003) which form thick brown jelly layers (Al-Hasan et al. 1990) that modify the rheological properties of seawater, produce foam that resembles whipped egg white (Dreyfuss 1962), and clog plankton and fish nets (Peperzak 2002). Large quantities of foam are generated in the turbulent surf zone of beaches along the North Sea and the Eastern English Channel (Lancelot et al. 1987; Seuront et al. 2006). Quantitative descriptions of the bulk-phase properties of seawater during phytoplankton blooms have estimated the changes in the viscous properties of seawater that are induced by phytoplankton mucus secretion (Jenkinson 1986, 1993; Jenkinson and Biddanda 1995; Seuront et al. 2006), and found a positive correlation between seawater viscosity and chlorophyll *a* concentration during *Phaeocystis* sp. blooms in the German Bight and the North Sea (Jenkinson 1993; Jenkinson and Biddanda 1995). More recent work (Seuront et al. 2006) showed a significant increase in seawater viscosity with the development of a *Phaeocystis globosa* bloom in the Eastern English Channel, and a positive correlation between chlorophyll concentration and seawater viscosity before foam formation as well as a negative correlation after foam formation. These results suggest that seawater viscosity is influenced by extracellular materials associated with colony formation and colony maintenance rather than by cell composition and standing stock.

In this context, the aim of this study is to use a microscale (5 cm resolution) two-dimensional sampler to investigate: (i) the heterogeneity of the microscale distributions of phytoplankton biomass and bulk-phase seawater viscosity, (ii) the potential changes in these distributions over the course of a *P. globosa* spring bloom and (iii) the nature of the correlation between seawater viscosity and phytoplankton before, during and after the formation of foam in the turbulent surf zone.

Materials and methods

Study site

Samples were taken from the end of a coastal pier situated in the intertidal waters of the French coast of the Eastern English Channel, approximately 20 m from the shoreline (50°45′896″ N, 1°36′364″ E), near Boulogne-sur-Mer (France). The Eastern English Channel is characterised by 3 to 9 m tides. These tides are characterised by a residual translation parallel to the coast, with nearshore coastal waters drifting from the English Channel into the North Sea. Coastal waters are influenced by freshwater run-off from the Seine estuary to the Straits of Dover. This coastal flow (Brylinski et al. 1991) is separated from offshore waters by a tidally maintained frontal area. The coastal flow water mass is characterised by its low salinity, high turbidity, high phytoplankton richness and high productivity compared to the oceanic offshore waters (Seuront 2005). This sampling site was chosen because the physical and hydrological properties are representative of the inshore water masses of the Eastern English Channel (Seuront 2005). Sampling was conducted at high tide, before, during and after the *Phaeocystis globosa* bloom in the Eastern English Channel on 26 September 2003, 5 March 2004, 18 March 2004, 1 April 2004, 20 April 2004, 10 May 2004, 25 May 2004 and 20 June 2004.

Microscale sampling device

A purpose-designed two-dimensional (2D) sampling device was developed to investigate the microscale distributions of chlorophyll *a* and seawater viscosity.