Biogeochemistry (2007) 83:49–60
DOI 10.1007/s10533-007-9082-6

ORIGINAL PAPER

# *Phaeocystis* colony distribution in the North Atlantic Ocean since 1948, and interpretation of long-term changes in the *Phaeocystis* hotspot in the North Sea

**W. W. C. Gieskes · S. C. Leterme · H. Peletier · M. Edwards · P. C. Reid**

Received: 13 October 2005 / Accepted: 12 June 2006 / Published online: 10 March 2007


**Abstract** Monitoring of *Phaeocystis* since 1948 during the Continuous Plankton Recorder survey indicates that over the last 5.5 decades the distribution of its colonies in the North Atlantic Ocean was not restricted to neritic waters: occurrence was also recorded in the open Atlantic regions sampled, most frequently in the spring. Apparently, environmental conditions in open ocean waters, also those far offshore, are suitable for complete lifecycle development of colonies (the only stage recorded in the survey).

In the North Sea the frequency of occurrence was also highest in spring. Its southeastern part was the *Phaeocystis* abundance hotspot of the whole area covered by the survey. Frequency was especially high before the 1960s and after the 1980s, i.e., in the periods when anthropogenic nutrient enrichment was relatively low. Changes in eutrophication have obviously not been a major cause of long-term *Phaeocystis* variation in the southeastern North Sea, where *total* phytoplankton biomass was related significantly to river discharge. Evidence is presented for the suggestion that *Phaeocystis* abundance in the southern North Sea is to a large extent determined by the amount of Atlantic Ocean water flushed in through the Dover Strait.

Since *Phaeocystis* plays a key role in element fluxes relevant to climate the results presented here have implications for biogeochemical models of cycling of carbon and sulphur. Sea-to-air exchange of $CO_2$ and dimethyl sulphide (DMS) has been calculated on the basis of measurements during single-year cruises. The considerable annual variation in phytoplankton and in its *Phaeocystis* component reported here does not warrant extrapolation of such figures.

**Keywords** Annual variation · North Sea hotspot · North Atlantic-wide · *Phaeocystis*

W. W. C. Gieskes
Department of Ocean Ecosystems,
University of Groningen, Haren, The Netherlands
e-mail: gieskess@xs4all.nl

S. C. Leterme
M.B.E.R.C., School University of Plymouth,
Plymouth, PL4 8AA, UK

H. Peletier
R.I.K.Z.-Rijkswaterstaat, Haren,
The Netherlands

S. C. Leterme (✉) · M. Edwards · P. C. Reid
S.A.H.F.O.S., Citadel Hill,
Plymouth, PL1 2PB, UK
e-mail: sophie.leterme@plymouth.ac.uk

## Introduction

In the North Atlantic and the North Sea seasonal variations in marine phytoplankton composition are well known, but annual variations in abundance

have hardly been described, with only a few exceptions. Monitoring has been maintained for several decades close to British (Russell et al. 1971), Dutch (Cadée and Hegeman 1991), German (Hickel et al. 1996) research institutes, off Belgium between 1988 and 2000 (Breton et al. 2006). Observed changes in plankton have been related to shifts in ocean current patterns (Russell 1935, 1973; Lindley et al. 1990; Taylor et al. 1998; Reid et al. 2003) that are assumed to be governed by large-scale meteorological phenomena (Beaugrand et al. 2002; Edwards et al. 2002; Reid and Edwards 2001; Drinkwater et al. 2003; Leterme et al. 2005; Breton et al. 2006), to climate (Radach 1984; Seuront and Souissi 2001; Reid et al. 1998), or to increased coastal eutrophication (Richardson 1989, 1997; Greve et al. 1996), but the response of plankton to anthropogenic interference (Cadée and Hegeman 2002; Beaugrand 2004) has not always been demonstrated in a convincing way.

The Continuous Plankton Recorder survey is the longest-running monitoring programme in the North Atlantic and the North Sea, with a remarkably wide coverage (Fig. 1a), based on one standard sampling method (Glover 1967; Colebrook 1975; Warner and Hays 1995). Since the time series spans several decades, it has been tempting to interpret striking changes in abundance of the plankton caught on the nets ('silks') of Hardy's recorders as the consequence of long-term environmental change because variations often took place simultaneously over very large areas (Colebrook and Robinson 1964; Edwards et al. 2002). Actually, it has often been taken for granted that hydroclimatic forcing in relation to global warming must have controlled the long- and short-term plankton variability. The northward shift in subtropical and temperate zooplankton groups and the gradual disappearance of cold-adapted copepod species in the eastern North Atlantic (Beaugrand et al. 2002) has indeed been quite conspicuous. However, trends in ocean water temperature, in the Atlantic multidecadal oscillation, or in the state of the North Atlantic oscillation and related hydrographical features (e.g., vertical stratification: Martin and Hall 1975; Fromentin and Planque 1996, Reid et al. 2001) could often only be related to the abundance of plankton components and transitions in taxonomic composition after sophisticated statistical treatment (Beaugrand et al. 2000, 2003; Beaugrand 2004) or on assumptions involving differential lags in the response of ecosystem components (Drinkwater et al. 2003; Kane 2005).

The Continuous Plankton Recorder survey has provided a tremendous data set on the occurrence of *Phaeocystis* sp. *Phaeocystis* was already known to vary as much as any other group of plankton in the North Atlantic (Owens et al. 1989) and the North Sea, in a way apparently independent of the phytoplankton in general or of other microalgal species groups such as dinoflagellates and diatoms (Gieskes and Kraay 1977a), for reasons not known at the time. We present here an overview of the occurrence of *Phaeocystis* throughout the North Atlantic. In our discussion we will focus on its presence in the North Sea, where it is most abundant. We offer an attempt to link occurrence to the pattern of long-term change in hydrographic events in the eastern North Atlantic. We end the presentation of our analysis by highlighting the biogeochemical implications of the long-term changes in the abundance of this species, which is known to affect profoundly the cycling and sea-to-air exchange of climate-relevant elements, especially carbon and sulphur, components in the greenhouse gases $CO_2$ and dimethyl sulphide (DMS; see review by Schoemann et al. 2005).

## Materials and methods

### The Continuous Plankton Recorder

The Continuous Plankton Recorder (CPR) survey consists of a dense network of transects across the North Atlantic and the North Sea. Plankton recorders are towed on a monthly basis at a depth of 8–10 m from ships-of-oppportunity that travel at 10–18 knots. The sampling mechanism inside the recorders consists of a narrow band of filtering silk (mesh 270 μm) that is driven by an impeller at the rear of the recorder at a speed adjusted according to the speed of the ship. The silk catches particles entering the 12 mm$^2$ aperture while it passes (at a rate of 10 cm per 10 nautical miles, 18.5 km) through the end of a wide tunnel behind the narrow opening in front. About 3 m$^3$