Journal of Marine Systems 158 (2016) 93–105

Contents lists available at ScienceDirect

Journal of Marine Systems

journal homepage: www.elsevier.com/locate/jmarsys

A survey of the summer coccolithophore community in the western Barents Sea

Jacques Giraudeau [a,*], Vivien Hulot [b], Vincent Hanquiez [a], Ludovic Devaux [a], Hélène Howa [b], Thierry Garlan [c]

[a] Université Bordeaux, CNRS, EPHE, UMR 5805 EPOC, Allée Geoffroy Saint-Hilaire, CS 50023, 33615 Pessac Cedex, France
[b] Université Angers, CNRS, UMR 6112 LPG-BIAF, Faculté des Sciences, 2 boulevard Lavoisier, 49045 Angers Cedex 1, France
[c] SHOM, Service Hydrographique et Océanographique de la Marine, 13 rue du Chatellier, 29200 Brest, France

ARTICLE INFO

Article history:
Received 27 August 2015
Received in revised form 17 February 2016
Accepted 29 February 2016
Available online 2 March 2016

Keywords:
Coccolithophores
Western Barents Sea
Summer phytoplankton community
Coccolith calcite

ABSTRACT

The Barents Sea is particularly vulnerable to large-scale hydro-climatic changes associated with the polar amplification of climate change. Key oceanographical variables in this region are the seasonal development of sea-ice and the location and strength of physico-chemical gradients in the surface and subsurface water layers induced by the convergence of Arctic- and Atlantic-derived water masses. Remote sensing imagery have highlighted the increasing success of calcifying haptophytes (coccolithophores) in the summer phytoplankton production of the Barents Sea over the last 20 years, as a response to an overall larger contribution of Atlantic waters to surface and sub-surface waters, as well as to enhanced sea-ice melt-induced summer stratification of the photic layer.

The present study provides a first thorough description of coccolithophore standing stocks and diversity over the shelf and slope of the western Barents Sea from two sets of surface and water column samples collected during August–September 2014 from northern Norway to southern Svalbard. The abundance and composition of coccolithophore cells and skeletal remains (coccoliths) are discussed in view of the physical–chemical–biological status of the surface waters and water column based on in-situ (temperature, salinity, fluorescence) and shore-based (microscope enumerations, chemotaxonomy) measurements, as well as satellite-derived data (Chl *a* and particulate inorganic carbon contents).

The coccolithophore population is characterized by a low species diversity and the overwhelming dominance of *Emiliania huxleyi*. Coccolithophores are abundant both within the well stratified, Norwegian coastal water — influenced shallow mixed layer off northern Norway, as well as within well-mixed cool Atlantic water in close vicinity of the Polar Front. Bloom concentrations with standing stocks larger than 4 million cells/l are recorded in the latter area north of 75°N. Our limited set of chemotaxonomic data suggests that coccolithophores contribute substantially (ca. 20% of the total Chl *a*) to the summer phytoplankton community which is made essentially of small-sized algal groups. Excluding the bloom area, coccolith calcite accounts for an average of 20% to the bulk particulate inorganic carbon content in the surface waters, and explains to some extent the satellite-derived spatial distribution of this parameter. Deep water living coccolithophore species thriving below the pycnocline as well as populations present in well-mixed cool Atlantic water are rapidly transferred to depth in the form of intact coccospheres down to at least 200 m. High amplitude internal waves which, according to our observations, affect a wide range of water depth up to the lower photic zone, might strengthen the vertical transfer of this sinking population.

1. Introduction

The hydrology of the shallow marginal Barents Sea contributes, together with the ocean circulation over Fram Strait, to the water mass exchanges between the Arctic and the Atlantic Oceans. Strong winds and convective overturning in winter, input of warm, nutrient rich Norwegian Atlantic Water (NwAW), and seasonal sea-ice melting combine to trigger an extensive spring bloom in the Barents Sea, with Chlorophyll *a* (Chl *a*) concentrations (a proxy for phytoplankton biomass) typically ranging from 2 to 10 mg/m^3 (Signorini and McClain, 2009). These values are among the highest recorded at the scale of the Arctic Ocean realm (Hunt and Drinkwater, 2005). Satellite imagery (Smyth et al., 2004; Burenkov et al., 2011) highlighted a profound change in phytoplankton dynamics and functional groups in surface waters of the Barents Sea over the last 25 years, a change which is characterized by the recurring development of extensive blooms of the coccolithophore *Emiliania huxleyi* during summer. This species reaches maximum concentrations in August, within a wide area of

* Corresponding author. Tel.: +33 5 40 00 88 60.
E-mail address: jacques.giraudeau@u-bordeaux.fr (J. Giraudeau).

http://dx.doi.org/10.1016/j.jmarsys.2016.02.012
0924-7963/

stratified, nutrient-depleted surface waters of the central and southern Barents Sea (Signorini and McClain, 2009). This phenomenon is part of the present general poleward expansion of *E. huxleyi* as reviewed by Winter et al. (2014). In the Barents Sea, it tends to extend nowadays further north, though with lower cell concentrations, along the Eurasian shelf break off Eastern Svalbard (Hegseth and Sundfjord, 2008). The contribution of the calcifying *E. huxleyi* to the high summer concentrations of particulate inorganic carbon (PIC) in surface waters of the central and southern Barents Sea has been testified by in-situ sampling and microscope observations of coccolithophore populations (Smyth et al., 2004). The most recent microscope observations of water samples collected within the central Barents Sea along 30°E and located within an area of high surface water backscattering from remote sensing observations, revealed coccolithophore concentrations ranging from 2 to 20 million cells/L (Burenkov et al., 2011; Hovland et al., 2014). The recent summer development of coccolithophore blooms in the Barents Sea has been related to the polar amplification of recent climate change which translates into positive temperature anomalies (increasing AW influence) and negative salinity anomalies (increasing seasonal sea-ice melting) (Smedsrud et al., 2013). Both anomalies act for the summer setting of a highly stratified photic layer (Smyth et al., 2004), the mixed layer depth (MLD) shoaling to a mean value of 10 m within the southern Barents Sea where coccolithophore blooms are the most frequently recorded (Signorini and McClain, 2009). This modern modification of phytoplankton dynamics and species groups potentially contributes to the on-going changes in the dynamics of higher trophic levels in the Barents Sea, from zooplankton to pelagic fish stocks (Dalpadado et al., 2012).

The present study provides a first thorough description of coccolithophore standing stocks and diversity in the western Barents Sea shelf and slope during the summer peak production period of this floral group in 2014. The abundance and composition of coccolithophore cells and skeletal remains (coccoliths) in surface and water column samples are discussed in view of the physical–chemical–biological status of the photic layer. Beside describing and understanding the bulk and species level pattern of coccolithophore distribution, we aim here at providing key information on the contribution of these calcareous prymnesiophytes to the summer phytoplankton population and surface water PIC within this polar region.

2. Oceanographic setting

The surface and intermediate circulation of the Barents Sea is characterized by the opposing flow of Atlantic and Arctic waters whose boundary is defined by the Polar Front (PF) (Fig. 1). The location of the PF in the western Barents Sea is closely controlled by the bottom topography and displays a meandering pattern steered by the bathymetrically shallow Spitsbergenbanken and the Storfjorden and Bjørnøyrenna glacial troughs (Loeng, 1991; Ozhigin et al., 2000). The North Cape Current (NCC), an extension of the Norwegian Atlantic Current (NwAC), which carries the main flow of Atlantic water into the Barents Sea, circulates over the latter, more extended trough. Further north along the Barents Sea margin and western Svalbard slope, the poleward flow of Atlantic water to Fram Strait is carried by the West Spitsbergen Current. The southward flowing East Spitsbergen Current and Persey Current transport cold and fresh polar waters to the central and western Barents Sea and merge over the Spitsbergenbanken to form the Bjørnøya Current (Loeng, 1991).

3. Material and methods

Surface and water column sampling took place as part of the marine geological and geophysical cruise MOCOSED 2014 of the French *Service Hydrographique and Oceanographique de la Marine* (SHOM) on-board the RV *Pourquoi Pas*? during August–September 2014. The investigated area covers the western Barents Sea shelf and slope from northern Norway to southern Svalbard (Fig. 1).

3.1. Oceanographic data

The environmental dataset is based on the integration of underway measurements, data obtained from multisensor vertical casts at CTD stations, and remote sensing imagery.

Sea-surface temperatures (SSTs) and salinities (SSSs) were measured at each underway coccolithophore sampling station (×50) from

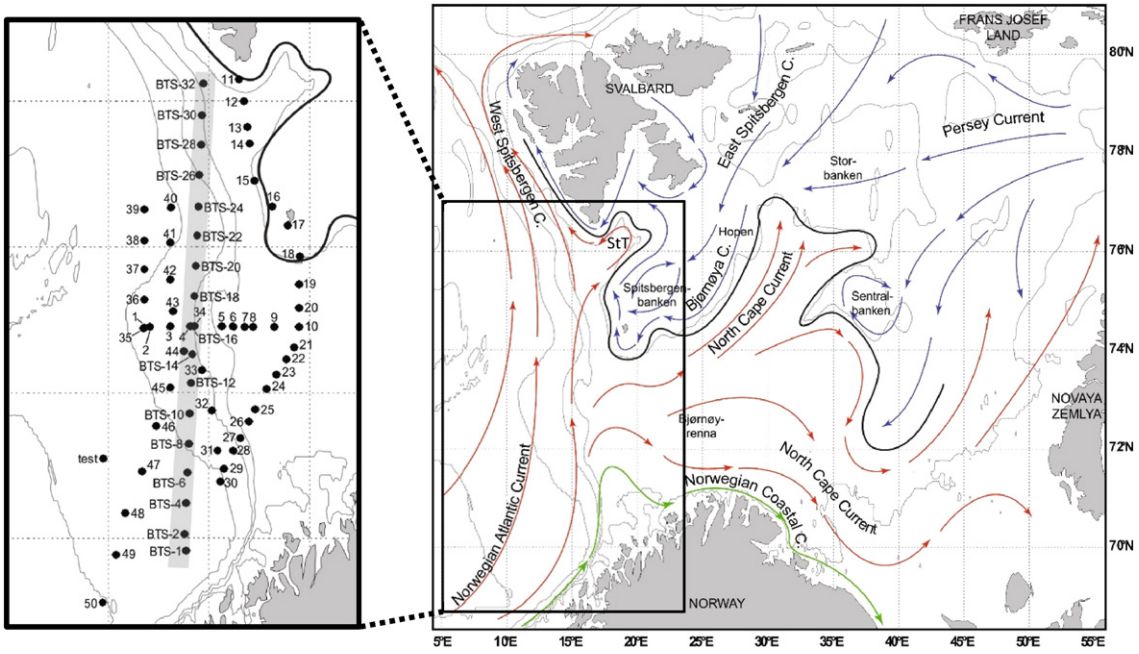

Fig. 1. Surface water circulation in the Barents Sea (after Solignac et al., 2009) and locations of the study area and coccolithophore sampling stations. The solid black line is the mean position of the Polar Front after Loeng (1991). Stations labeled "BTS" are part of the water column transect (gray rectangle) within the zoom box. All other labels correspond to underway surface water samples. StT: Storfjorden trough.