

Comparative dynamics of pelagic and benthic micro-algae in a coastal ecosystem



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ABSTRACT

Together with phytoplankton, microphytobenthos (MPB) play an important role in the overall food web structure of coastal ecosystems by regulating nutrient fluxes, oxygen concentration and sediment stability in the ecosystem. Although there are many studies on phytoplankton, MPB dynamics in the subtidal zone are largely unknown. In this study, we carried out a whole-year survey to investigate the seasonal dynamics of phytoplankton and MPB biomass simultaneously in relation to the environmental physico-chemical parameters. We show that phytoplankton and MPB do not follow the same dynamics with MPB being the first to increase in the season. It constitutes a large energy input to the ecosystem from the beginning of spring (with 60% of the total biomass until April). The system then moves from a system dominated by benthic biomass in early spring to a system where the pelagic biomass dominates. Among resources that MPB and phytoplankton have to share, light seems to trigger the MPB bloom as soon as maximum bottom PAR is reached, i.e. one month earlier than the phytoplankton bloom in the water column. With regard to nutrients, the lack of phosphorus can be put forward to explain the decline of MPB biomass at the beginning of April, whereas the phytoplankton decline in the first week of May coincides with silicic acid deficiency. Dissolved inorganic nitrogen then becomes potentially limiting in the water column until the end of October. Competition with macroalgae at the bottom and grazing were also considered as being possible factors for the disparate course of phytoplankton and MPB dynamics. Further investigations are needed to give a more detailed picture on the interactions and feedback loops between MPB and phytoplankton. However, although benthic-pelagic relationships are complex, this study indicates the need to integrate such fundamental coupling to a thorough understanding of ecosystem dynamics and functions.

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1. Introduction

In coastal waters, both phytoplankton and microphytobenthos (MPB) are principal components in the diet of higher trophic levels (Gillespie et al., 2000). Although phytoplankton has been greatly documented, the MPB is often understudied. As the presence of MPB is not always obvious, MacIntyre et al. (1996) called it the “secret garden”. However, in intertidal and some shallow subtidal systems, MPB can play an equally significant role: its biomass can

be equal to or even surpass the biomass of the overlying phytoplankton (Cadee and Hegeman, 1977; Lukatelich and McComb, 1986; Underwood et al., 1998). By its photosynthetic activity, it also regulates the concentration of oxygen and nutrient fluxes at the sediment–water interface with a significant impact on their availability to phytoplankton in the water column (Ragueneau et al., 1994; Ní Longphuirt et al., 2009). MPB can affect the nutrient flux by assimilating nutrients from overlying water as well as from underlying porewater and also can influence the nutrient dynamics of the water column by the ‘coupled nitrification-denitrification’ pathway (Underwood, 2001).

MPB differ from phytoplankton in terms of both ecology and taxonomy (MacIntyre et al., 1996; Cahoon et al., 1999; Underwood

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and Kromkamp, 1999). Some general patterns of phytoplankton dynamics in temperate natural reservoirs have already been established (Reynolds 1984a,b; Sommer et al., 1986). The spring bloom initiated by the abundance of nutrient and light, is generally comprised of diatoms, cryptophytes, chrysophytes or chlorophytes, which is followed by a “clear water phase” induced by the grazers in the late spring or early summer. After this, the summer brings in a period of stratification where nutrient limitation and grazing result in a controlled growth of phytoplankton which recovers a little in late summer and autumn due to deeper mixing before winter reduces the community biomass (Grover and Chrzanowski, 2005). Temperature and thermal stratification have been considered to be the two prime factors for the dynamics of phytoplankton in temperate areas together with nutrients, light and grazing being the subsidiary ones (Reynolds 1984a,b; Sommer et al., 1986). Benthic flux is another factor which influences both the community composition and primary production of phytoplankton and MPB. Although highly variable, the biological factors such as bioturbation or bioirrigation have been observed to induce nutrient fluxes in specific time scales (Marinelli, 1994; Ragueneau et al., 2005), as in the Bay of Brest where *Crepidula fornicata* influences DSI flux and thus prohibits Dinophyta harmful algal blooms in summer months (Del Amo et al., 1997; Chauvaud et al., 2000; Ragueneau et al., 2005). However, although a wealth of data is available on global phytoplankton growth (Longhurst et al., 1995), complementary benthic studies are rather scarce (Cahoon et al., 1999). In addition, most work on MPB has been in intertidal zones, while subtidal zones have generally been neglected (Light and Beardall, 1998), except for a few studies (e.g. Sundback and Jonsson, 1988; Delgado, 1989; Cahoon and Laws, 1993; Schreiber and Pennock, 1995 etc.). The seasonal dynamics of subtidal MPB have been observed to be following the yearly pattern of irradiance and show higher degrees of seasonality compared to intertidal MPB which are subjected to extremes of irradiance exposures (Underwood, 2001). However, studies about the simultaneous dynamics and interactions between both pelagic and benthic compartments are missing. These investigations are important in coastal areas to better understand how phytoplankton and MPB share the resources necessary for their growth, i.e. light and nutrients, for which competition is highly asymmetric. While pelagic algae intercept the flux of light from the surface to the bottom, benthic algae intercept the flux of nutrients from the sediment to the water column. These feedback loops can enhance the dominance of either algal group with major alterations to the entire trophic web (Reynolds, 2008).

The objective of this study has been to interrogate, from weekly to seasonal time scales, the phytoplankton and epibenthic (attached to hard surfaces) MPB dynamics (biomass, particulate matter and biogenic silica) in a subtidal area, in relation to the environmental physico-chemical parameters.

2. Material and methods

2.1. Strategy of sampling

The Bay of Brest is a temperate, semi-enclosed, shallow-water marine ecosystem on the coast of Brittany in northwestern France. It is 180 km² and its average depth averages around 8 m although the bay constitutes a coastal macrotidal system, having the maximal tidal amplitude reaching over 8 m during spring, and the maximal tidal current nearing 2.6 m/s (Chauvaud et al., 2000). The rivers Penfeld, Aulne and Elorn provide freshwater input, while the adjoining Iroise Sea is connected via a narrow (1.8 km wide) strait that allows fast mixing exchanges with Atlantic water (Le Pape et al., 1996). The study site is located at Lanvéoc (48° 17'41.023"N – 4° 27'12.063"W) in the southern

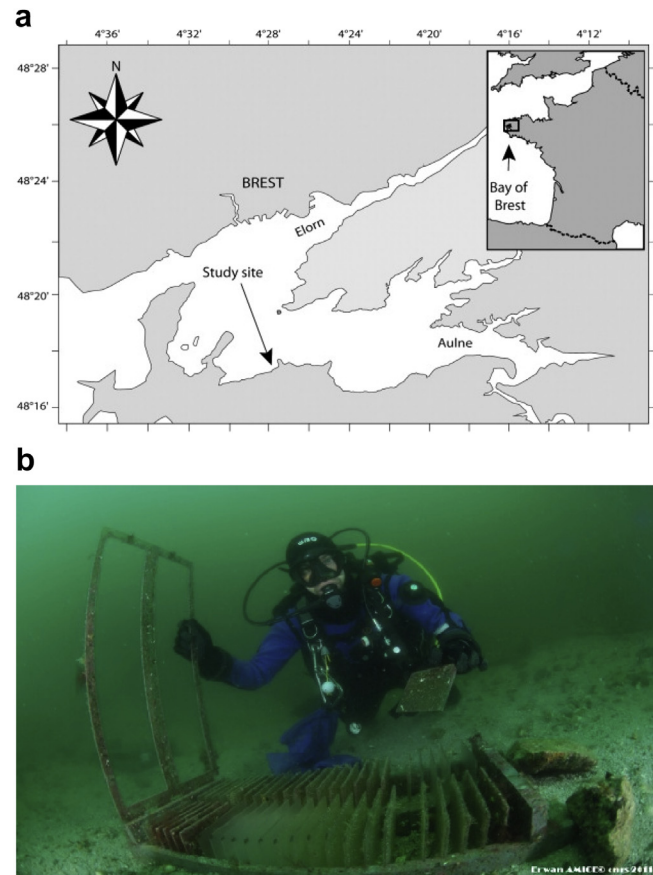


Fig. 1. (a). Map of the Bay of Brest (Adapted from Foullaron et al., 2007). The arrow indicates the sampling station (Lanveoc). (b). Photograph of the series of plates at the sampling site used for the study of MPB.

part of the Bay of Brest (Fig. 1a). The fieldwork was carried out in 2011, from the beginning of February to the end of October. Samples were taken from the LEMAR or IUEM Research vessels once a week, intensified to twice a week for the period around the spring bloom (from March to May). Sampling was performed as much as possible at medium tidal coefficient and around mid-tide. These conditions were chosen to facilitate comparisons between the cruises. Water column samples were collected with a 12 L Niskin bottle at 3 depths: surface, middle and bottom (9 m).

MPB was studied on artificial support which simulated a hard surface substratum. A series of plexiglass plates (12 × 15 cm) were placed at the sediment surface at the site of sampling in June 2010, i.e. they were at least 6 months old when we started the survey (Fig. 1b). Such plates have been shown to be good mimics of the natural substratum (Cattaneo and Kalf, 1978) and allow overcoming the high variability of MPB population within sediment due to the heterogeneity of the substratum. One plate was taken out every week by scuba divers, starting from January 2011, and twice per week during the spring period. Immediately after collecting, the biomass was scrapped off by a standard toothbrush and suspended in 2 L of filtered (0.6 μm) bottom sea water. Subsamples were taken for subsequent analyses.

2.2. Physical parameters

A CTD profiler Sea-Bird SBE-911, equipped with a photosynthetically active radiation (PAR) sensor was used to measure

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