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Size-fractionated phytoplankton biomass and nitrogen uptake in response to high nutrient load in the North Biscay Bay in spring

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ABSTRACT

The influence of continental nutrient inputs on nitrogen uptake (nitrate and ammonium) by size-fractionated plankton was investigated on the continental shelf of the North Biscay Bay during early spring. As a general trend, larger phytoplankton ($>10\,\mu m$) contributed significantly to the biomass and N uptake in nitrate-repleted waters and this was particularly marked in the inshore waters where nitrate concentrations were above of 7–10 $\mu mol\,L^{-1}$. In these waters, the relative contribution of nitrate to N uptake for the larger phytoplankton was generally higher than 50%, whereas most of the N used by the smaller cells ($<10\,\mu m$) was in the form of ammonium. In the central part of the shelf and in the oceanic waters, the N nutrition of the two size fractions was more variable, but in almost all cases, the relative contribution of nitrate to total N uptake was greater for the large phytoplankton size fraction compared to the small one. Analysis of the nitrate taken up indicated that about 45% of the daily dissolved inorganic nitrogen inputs by the Loire estuary, mainly as nitrate, may be potentially trapped in the inshore waters in early spring and, thus should not reach the central part of the shelf.

1. Introduction

The North Biscay Bay is characterised by a broad continental shelf and is subjected to very high freshwater inputs from the Loire Estuary. This outflow induces an important physical forcing which can greatly influence phytoplankton production. For example, the haline stratification due to freshwater runoff was proved to be responsible for late winter phytoplankton developments on the Armorican shelf (Morin et al., 1991) and in the coastal waters near the mouth of the Loire estuary (Chapelle et al., 1994; Lampert et al., 2002). Recently, Guillaud et al. (2008) suggested that this haline stratification, when coinciding with anticyclonic weather conditions in late winter–early spring, may also impact the phytoplankton behavior in the central part of the shelf. In addition to this physical regulation, freshwater inputs from the Loire estuary contribute significantly to a nutrient enrichment over a large domain of the continental shelf, and this can lead to increased algal growth and biomass (Loyer et al., 2006). An important aspect of this nutrient enrichment is the strong imbalance in N/Si and N/P ratios, as an excess of N relative to Si and P inputs. The high nutrient levels and these nutrient ratio alterations could be expected to impact the phytoplankton community size-structure as suggested by others studies (Smayda, 1990; Riegman et al., 1993; Yin et al., 2001). In addition, they can also influence the export of the biomass produced to depth and to higher trophic levels which largely depends on the size of primary producers (Goldman, 1988; Legendre, 1990; Tremblay et al., 2000).

In this study, we report nitrate and ammonium uptake rates measured for two planktonic size fractions (total community and $<10\,\mu m$) over the continental shelf of the North Biscay Bay in early spring. The main objectives were to describe the spatial variability of nitrogen uptake in response to the nutrient inputs by the Loire estuary and to investigate the relationships between N utilization and the phytoplankton size-structure. The results are discussed with respect to the proportion of N inputs that can be potentially trapped in the inshore waters.

2. Material and methods

Sampling was performed during the Gasprod 2002 cruise (N.O *Thalassa*) which was intended to assess the biogeochemical

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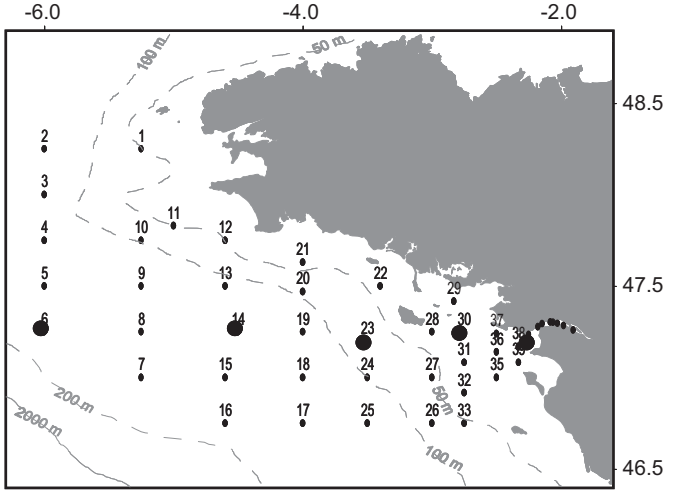

Fig. 1. Locations of numbered stations. Black circles indicate the stations where samples were collected at five optical depths.

impact of rivers plumes upon the ecosystems of the Atlantic continental margins. A network of 24 stations located from inshore-to-offshore waters (150 m depth) was sampled between 9th and 20th April, 2002 (Fig. 1). At each station, vertical profiles of temperature, salinity, photosynthetically active irradiance (SBE25 CTD probe Sea Bird Electronics, Washington, USA) and *in situ* fluorescence (sensor Seapoint, Exeter, USA) were obtained in order to describe the vertical structure of the water column. Samples for analysis of nutrient (nitrate, ammonium, phosphate and silicate), chlorophyll *a*, particulate organic nitrogen and for examining uptake and regeneration fluxes of dissolved inorganic nitrogen (DIN) were collected in surface waters at all stations and at five optical depths for five stations located along a transect from the coast to the continental slope.

Nitrate, silicate and phosphate concentrations were measured with a Technicon Analyser II following the procedure described by Tréguer and Le Corre (1975). Ammonium concentrations were determined manually in triplicate by the indophenol blue method (Koroleff, 1970). Analytical precisions for the measurements of nitrate, silicate, phosphate and ammonium were, respectively of ± 0.05, ± 0.05, ± 0.02 and $\pm 0.02\,\mu mol\,L^{-1}$. Chlorophyll *a* (Chl. *a*) was estimated directly by filtration of 500 mL of sea water on 25-mm-Whatman-GF/F-filters for the total community, and after filtration through a 10-μm-pore-size-polycarbonate filter for the $<10\,\mu m$ size fraction. The filters were stored immediately at $-80\,^{\circ}C$ and analysed at the end of the cruise. Pigments were extracted with an acetone–water mixture (90/10, v/v) and measured by high-performance liquid chromatography (HPLC, ThermoFisher Scientific, Bremen, Germany) using the reverse-phase HPLC method described by Wright et al. (1991) and slightly modified by Lampert et al. (2002).

Nitrate and ammonium uptake rates were measured with ^{15}N-labeled substrates and ammonium regeneration using the isotope dilution method. Uptake rates were measured in the two size fractions (total community and $<10\,\mu m$). The ^{15}N tracer, as $Na^{15}NO_3$ or $^{15}NH_4Cl$ (99 at% ^{15}N, CEA, France) was added to the samples as far as possible at about 10% of the ambient concentration. Immediately after addition of the tracer, half of the sample was filtered onto pre-combusted-Whatman-GF/F-filters to determine the zero time ^{15}N enrichment of the particulate and dissolved pools. The remaining fraction was incubated in 1 L polycarbonate bottles under simulated *in situ* conditions for 24 h. The incubators were covered with calibrated nickel screen to reduce the photosynthetically active radiation (PAR) to a level equivalent to that prevailing at the sampling depth. The ambient temperature was maintained constant with a continuous flow of sea water. Following incubation, the samples were filtered onto pre-combusted-Whatman-GF/F-filters under a <100 mm Hg vacuum to obtain the uptake rates by the total community and after prefiltration through a 10 μm-pore-size-polycarbonate filters for the $<10\,\mu m$-size fraction. In case of ammonium experiments, the filtrate was also recovered; an aliquot was used immediately for ammonium measurements, and the remaining stored with $HgCl_2$ for isotope ratio measurements. The GF/F-filters were oven-dried (60 °C) and stored in clean plastic vials. Ammonium from the filtrate was extracted by

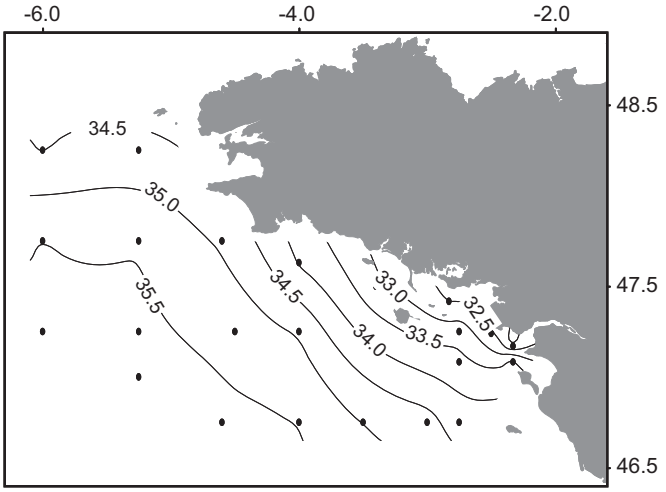

Fig. 2. Distribution of surface salinity.

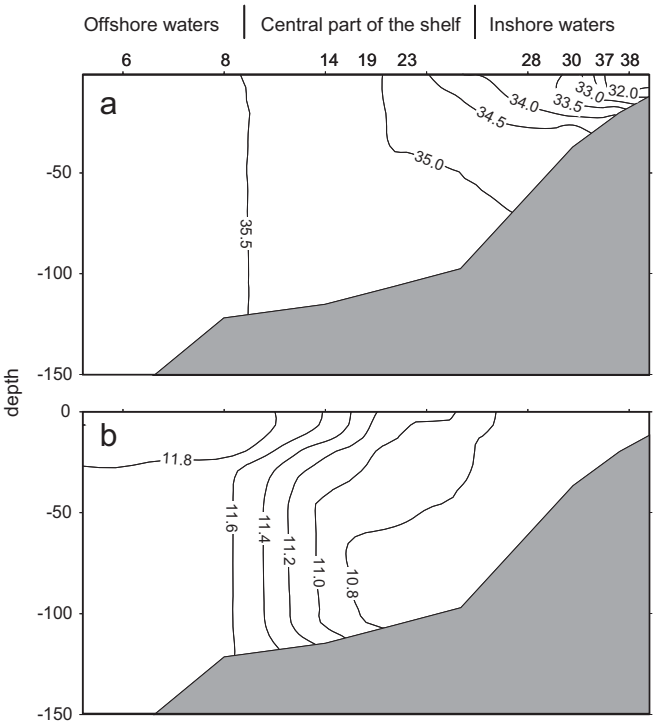

Fig. 3. Vertical distributions of (a) salinity and (b) temperature along transect from the Loire estuary to the continental slope.