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Nutrient Regeneration at Bottom after a Massive Spring Bloom in a Subarctic Coastal Environment, Funka Bay, Japan

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Nutrient regeneration and oxygen consumption after a spring bloom in Funka Bay were studied on monthly survey cruises from February to November 1998 and from March to December 1999. A high concentration of ammonium (more than 4 μmol l^{-1}) was observed near the bottom (80–90 m) after April. Phosphate and silicate gradually accumulated and dissolved oxygen decreased in the same layer. Salinity near the bottom did not change until summer, leading to the presumption that the system in this layer is semi-closed, so regenerated nutrients were preserved until September. Nitrification due to the oxidation of ammonium to nitrate was observed after June. Nitrite, an intermediate product, was detected at 4–7 μmol L^{-1} in June and July 1999. Assuming that decomposition is a first order reaction, the rate constant for decomposition of organic nitrogen was determined to be 0.014 and 0.008 d^{-1} in 1998 and 1999, respectively. The ammonium oxidation rate increased rapidly when the ambient ammonium concentration exceeded 5 μmol L^{-1}. We also performed a budget calculation for the regeneration process. The total amount of N regenerated in the whole water column was 287.4 mmol N m^{-2} in 4 months, which is equal to 22.8 gC m^{-2}, assuming the Redfield C to N ratio. This is 34% of the primary production during the spring bloom and is comparable to the export production of 25 gC m^{-2} measured by a sediment trap at 60 m (Miyake *et al.*, 1998).

Keywords:
· Remineralization,
· nitrification,
· oxygen consumption,
· stoichiometry,
· Funka Bay.

1. Introduction

In subarctic and temperate coastal regions, an intense phytoplankton bloom occurs in spring. Most of the production is classified as a new production because the nutrients utilized are supplied from the deeper layer as a result of vertical convection in winter. A massive spring bloom occurs in Funka Bay, consisting of diatom species (Odate, 1987; Maita and Odate, 1988; Kudo and Matsunaga, 1999). Nitrate depletion terminates the spring bloom in Funka Bay and silicate is further consumed after the depletion of nitrate (Kudo *et al.*, 2000). One third of annual primary production occurs during the spring bloom in the bay (Kudo and Matsunaga, 1999). Some of the carbon produced is exported to the deeper layer as settling particles. A large settling flux is observed a few weeks after the peak of the spring bloom in Funka Bay (Miyake *et al.*, 1998).

Settling and sedimentation of particulate organic matter onto the sediment surface are the fundamental processes connecting pelagic with benthic ecosystems. Decomposition of organic matter on the sediment surface layer is highly dependent on these processes. More than 80% of organic nitrogen compounds that deposit on the sediment are remineralized and return to the euphotic layer (Wollast, 1991). This benthic flux may support further primary production in the euphotic layer.

Decomposition of organic substances progresses through exudation by grazers or heterotrophic bacterial activity (Dickson and Wheeler, 1995; Ward, 2000). Nitrogen has several inorganic forms and ammonium is the first breakdown product of organic nitrogen. This ammonium is oxidized to nitrite and then to nitrate (nitrifica-

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