ECOLOGY OF ARCHAEA IN THE SOUTHERN NORTH SEA

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Recently, we came to know that Archaea occur in virtually all oceans and shelf seas. To gain a better understanding of the ecology of Archaea in coastal seas, the abundance and diversity of the two main groups of Archaea, the Crenarchaeota and the Euryarchaeota, was studied in the Southern North Sea during three cruises with the RV Pelagia in February 2003 and April 2004 and with the RV Alkor in August 2004. Overall, the Crenarchaeota are more abundant during the winter, when nutrient concentrations were high and light was too dim for algae to grow. With the onset of the phytoplankton spring bloom, they are outcompeted and Euryarchaeota become more abundant. In the two areas that were characterized by the highest nutrient concentrations, crenarchaeotal cell number remained high throughout the year. The Crenarchaeota obtain their energy from nitrification, a process whereby ammonium is oxidized into nitrite. Our data show that crenarchaeotal nitrification may explain the observed seasonal and spatial differences in archaeal community structure and abundances.

Following considerable advances in genetics in the last decades, life on Earth has been divided into three domains: Bacteria, Archaea and Eukarya. The first two domains comprise unicellular organisms, while the latter include all higher plants and animals. Traditionally Archaea were thought to only dwell in extremely warm or salty environments, but new approaches have clearly established that they are abundant in the water column of all marine environments. Marine Archaea consist of two major groups, the Crenarchaeota and the Euryarchaeota. Recent time series analysis carried out at the Royal NIOZ revealed that Crenarchaeota were abundant in the Wadden Sea in late autumn and winter, while Euryarchaeota were present in spring and summer. We found a similar pattern at six out of eight stations in the Southern North Sea (Fig.1.). Qualitative DNA analysis

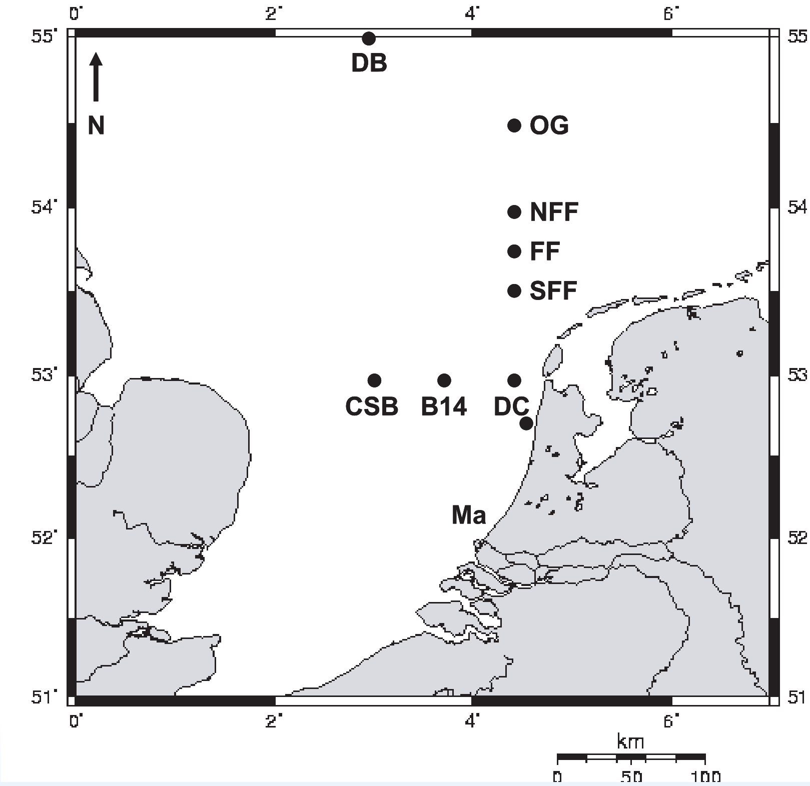

Fig. 1. Map showing the location of the study sites in the Southern North Sea. Abbreviations = DC: Dutch Coast; CSB: Central Southern Bight; B14: Breeveertien; SFF: South Frisian Front; FF: Frisian Front; NFF: North Frisian Front; OG: Oyster Grounds; DB: Dogger Bank.

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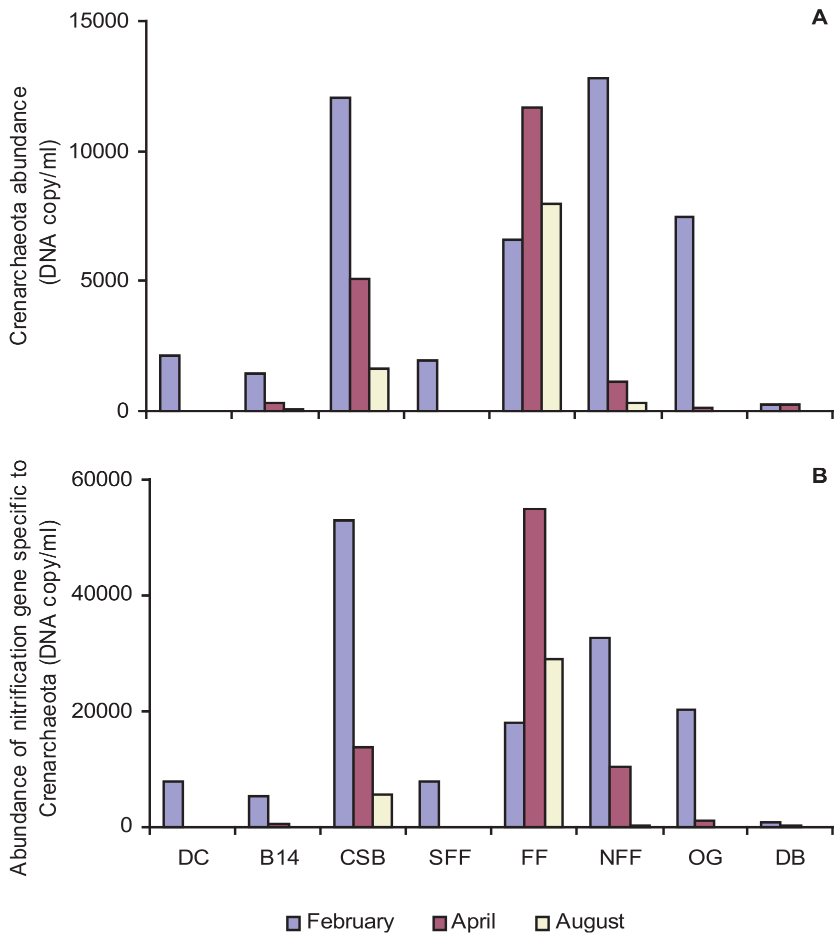
Fig. 2. Abundances of Crenarchaeota (A) and of the nitrification gene specific to Crenarchaeota (B) in the surface seawater of the Southern North Sea in three different seasons. Station abbreviations are explained in Fig. 1.



showed that there is a clear overall seasonality, with crenarchaeotal DNA detected in February and Euryarchaeota mostly occurring in April and August. The Frisian Front and the Central Southern Bight are the exceptions since crenarchaeotal DNA was also detected in April and August. These two stations also show the highest abundances of Crenarchaeota in all seasons (Fig. 2.).

One of the major questions to ask in microbial ecology is ‘what is the energy source of an organism’. Nitrification, the process of energy generation whereby ammonia is first oxidized to nitrite and then to nitrate, was thought to be used by bacteria only. Very recently, however, data from different laboratories, including ours, have demonstrated that marine Crenarchaeota are also able to oxidize ammonia into nitrite. Our North Sea data confirm that Crenarchaeota are nitrifyers, since their abundances correlate well with the amount of their nitrification gene (Fig. 2.). In addition, high ammonium concentrations in winter are always associated with elevated crenarchaeotal abundances and, inversely, low levels in spring and summer concur with low crenarchaeotal cell numbers.. So, fluctuations in ammonium concentrations throughout the year can explain the strong seasonality in crenarchaeotal abundance. The spatial variability may also be explained by differences in ammonium concentrations, since a high correlation was, for instance, found in August between crenarchaeotal abundances and ammonium concentrations at different stations (Fig. 3.).

Our study shows that In summer crenarchaeota in the Southern North Sea are mostly nitrifyers. This implies that Crenarchaeota play an important role in the oceanic biogeochemical nitrogen cycle. On the other hand, the energy source of Euryarchaeota is still unknown and remains one of the major challenges for our future research on this topic.

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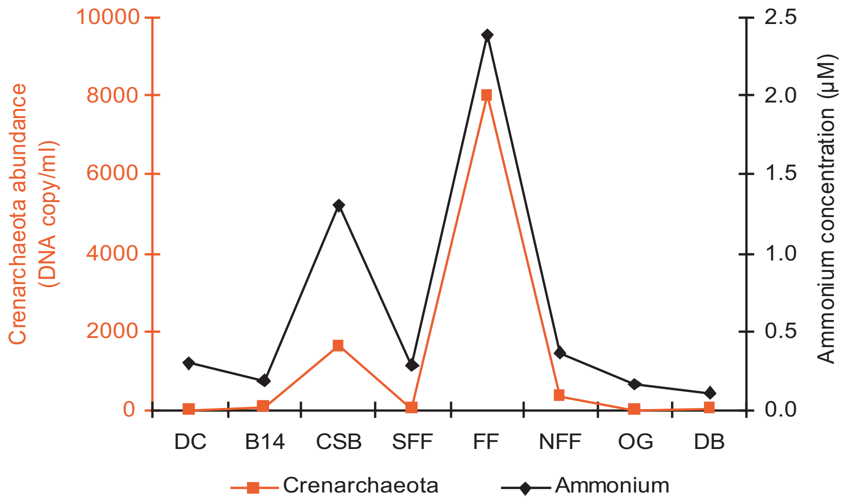

Fig. 3: Abundances of Crenarchaeota and ammonium concentrations in the surface seawater of the Southern North Sea, sampled in August 2004. Station abbreviations are explained in figure 1.

In the framework of the Ocean Facilities Exchange Group (OFEG), the last North Sea cruise of this programme was with the German RV Alkor.

Seawater sampling from the CTD-frame for DNA and lipid analysis on the RV Pelagia.