DISTRIBUTION AND ACTIVITY OF BACTERIA AND ARCHAEA IN THE DEEP NORTH ATLANTIC OCEAN

Marta M Varela *, Hendrik M Van Aken and Gerhard J Herndl
Department of Biological Oceanography, Royal Netherlands Institute for Sea Research, PO Box 59, NL-1790 AB Den Burg, The Netherlands - varela@nioz.nl

Abstract
We determined the distribution and activity of the major prokaryotic groups (Bacteria, *Cren-* and *Euryarchaeota*) in the deep water masses of the eastern North Atlantic. The bacterial contribution to total picoplankton abundance was rather homogeneous, comprising 50% of DAPI-stainable cells. *Euryarchaeota* cells were hardly present, while the percentage of *Crenarchaeota* ranged from <5 and >20% in subsurface and deep waters, respectively. Both Archaea and Bacteria were taking up D- and L-Aspartic acid, while we did not find any evidence that *Crenarchaeota* take up inorganic carbon, suggesting that they are heterotrophs incorporating mainly D-amino acids.
Keywords : Bacteria, Carbon, Deep Waters.

Prokaryotic (Bacteria and *Archaea*) plankton are the major drivers of biogeochemical cycles in the ocean.While the importance of bacteria in the biogeochemical cycles of marine ecosystems is well established, particularly for surface waters, little is known about the distribution and metabolic activity of the prokaryotic community in the meso- and bathypelagic realm of the ocean. Recent studies found that *Archaea* have the potential to use both inorganic and organic carbon [1-2] as energy source in the deep ocean. However, more information is needed in order to identify the distribution of group-specific prokaryotic activity in deep water.
Sampling of meso- and bathypelagic waters was carried out along a 4000-km transect covering the major deep water masses of the eastern North Atlantic. Water samples were taken from the 100m layer (subsurface), the oxygen minimum zone (O_2-min),the Mediterranean Sea Outflow Water (MSOW) in the subtropical gyre, the Antarctic Intermediate Water (AAIW) in the North Equatorial Counter Current, the Northeast Atlantic Deep Water (NEADW) and the Lower Deep Water (LDW). D- and L-aspartic acid (Asp) incorporation was measured on the bulk prokaryotic community and archaeal production via the incorporation of ^{14}C-bicarbonate. We compared bulk activity measurements with that on a single cell level using catalyzed reporter deposition fluorescence in situ hybridization combined with microautoradiography(MICRO-CARD-FISH).
The bacterial contribution to total picoplankton abundance ranged from 40 to 55% of DAPI-stainable cells both in the subtropical gyre and North Equatorial Counter Current stations. Generally, the vertical distribution was rather homogeneous and lacked a clear latitudinal pattern. *Euryarchaeota* were hardly present along the transect, comprising always <5% of DAPI-stainable cells. *Crenarchaeota* exhibited a more patchy distribution throughout the transect. The percentage of total picoplankton identified as *Crenarchaeota* ranged between<5% and >20% in subsurface waters (around 100m depth) and the LDW, respectively. In general, *Crenarchaeota* were less abundant in the subtropical gyre waters(<10% of the picoplankton community) than in the North Equatorial Counter Current stations (up to 25% of total picoplankton cells) (Figure 1).

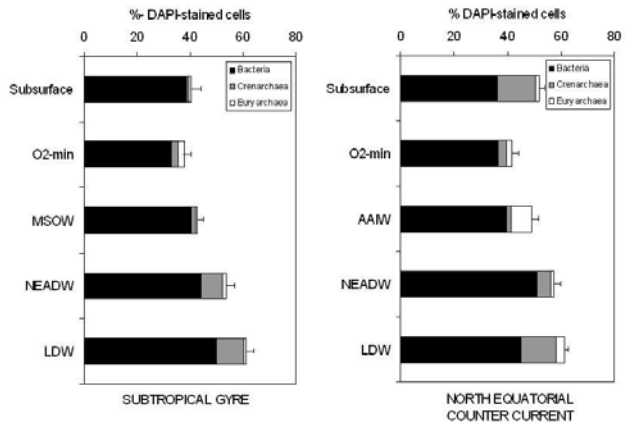

Fig. 1. Abundance of Bacteria and Archaea enumerated with CARD-FISH in the different water masses of the North Atlantic.

Mean L-Asp bulk uptake rates decreased from 8.3 pmol $L^{-1}h^{-1}$ at 100m depth to 0.03 pmol $L^{-1}h^{-1}$ in the NEADW, while D-Asp decreased from 0.5 pmol $L^{-1}h^{-1}$ at 100 m depth to 0.005 pmol $L^{-1}h^{-1}$ in the NADW. The ratio of D-/L- Asp uptake by the prokaryotic community increased from the subsurface layer (D-/L- Asp uptake ratio ∼0.09) to the deeper layers reaching a ratio close to 1 at 4000 m depth (Figure 2).

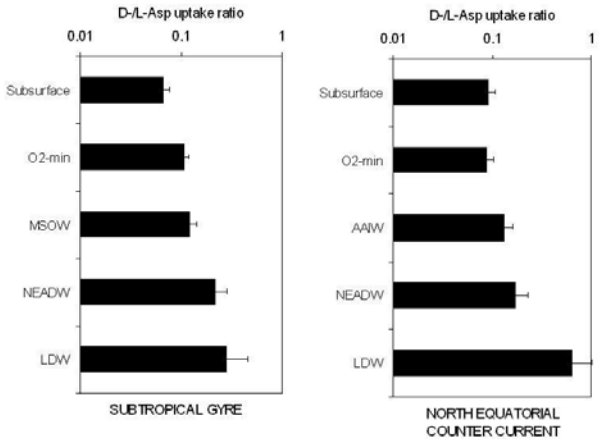

Fig. 2. D-/L-Asp uptake ratio derived from the bulk prokaryotic community measurements in the different water masses of the North Atlantic.

Archaeal production generally followed the same decreasing trend with depth as the prokaryotic production, declining from 295 μmol C m^{-3} day^{-1}at a depth of 100 m to 85 μmol C m^{-3} day^{-1} in the oxygen minimum layer at a depth of 500 m. However, in the deep ocean we could not measure any inorganic carbon incorporation. Using MICRO-CARD-FISH, we found that both *Archaea*and Bacteria were taking up D- and L-Asp. The percentage of *Crenarchaeota* taking up D-Asp was highest in the LDW of the North Equatorial Counter Current, while we did not find any evidence that *Crenarchaeota* take up inorganic carbon. Thus, in contrast to recent findings showing that *Crenarchaeota* are chemoautotrophic in the mesopelagic waters, using inorganic carbon as a carbon source and oxidizing ammonia as an energy source [4], in bathypelagic waters, *Crenarchaeota* are likely heterotrophs using efficiently D-amino acids.

References

1 - Herndl G.J., Reinthaler T., Teira E., van Aken H.M., Veth C., Pernthaler A. and Pernthaler J. 1995. Contribution of *Archaea* to total prokaryotic production in the deep atlantic ocean. *Appl. Environ. Microbiol.,* 71: 2303-2309.
2 - Teira E., Lebaron P., van Aken H.M., Herndl G.J. 2006b. Distribution and activity of Bacteria and Archaea in the deep water masses of the North Atlantic. Limnol. Oceanogr., 51:2131-2144.
3 - Wuchter C., Abbas B., Coolen M.J.L., Herfort L., Bleijswijk J., Timmers P., Strous M., Teira E., Herndl G.J., Middelburg J.J., Schouten S. and Damste J.S.S. 2006. Archael nitrification in the ocean. *PNAS*, 103:12317-12322.