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Vertical distribution (0–1000 m) of gelatinous zooplankton and particulate matter (60µm<<5mm) along the Mid Atlantic ridge in the North Atlantic. Potential impact of appendicularians on particle aggregation.

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Abstract

The vertical distribution (0-1000 m depth) of macrozooplankton along the northern portion of the Mid-Atlantic Ridge (59°58N, 25°53W to 41°29N, 28°19W) was investigated during the MARECO program (June and July 2004) using the Underwater Video Profiler (UVP). Twelve relatively large (> 1 cm) groups were selected from the recorded images: sarcodines (with two sub-groups), crustaceans (excluding copepods), chaetognaths, ctenophores (with two sub-groups cydippids and lobates), siphonophores, medusae (with three subgroups *Aeginura grimaldii*, *Aglantha* spp. and all other medusae), appendicularians, and thaliaceans. The numerically dominant groups over the whole area were crustaceans (26%), medusae (20%) and appendicularians (17%). The gelatinous fauna were consistently most numerous between 400-900 m. Appendicularians, ctenophores and A. grimaldii occurred mostly below 300 m (maximum concentrations of 75, 58, and 30 individuals 100m-3, respectively). The macrozooplankton community below 200 m varied with the spatial distribution of the four regions defined by the temperature and salinity profiles. The results suggest that the Sub-Polar Front restricts the mixing of macrozooplankton communities down to 1000 m depth. The observed relationship between appendicularians and biovolume and size of particles is investigated in the four oceanic regions.

Keywords: Gelatinous zooplankton, mesopelagic zooplankton, Sub Polar Front, North Atlantic, Underwater Video Profiler, MARECO .

Introduction

Quantification of midwater macrozooplankton on temporal and spatial scales is basic to predicting the vertical flux of elements to the deep sea (Fowler *et al.*, 1991; Wassmann *et al.*, 2000) because these mesopelagic fauna are known to fragment, re-mineralize and consolidate particles sinking through the water column (Dagg, 1993; Lampitt *et al.*, 1993; Steinberg *et al.*, 1997; Wishner *et al.*, 1998; Stemmann *et al.*, 2004). Within the midwater community, knowledge of gelatinous organisms is particularly sparse because these animals are sampled poorly with nets (Robison, 2004; Vinogradov, 2005). However, direct observations and imaging technologies have revealed that gelatinous fauna are often major components of mesopelagic food webs (Steinberg *et al.*, 1997; Robison, 2004; Stemmann et al., 2007). Among the different groups, the appendicularians are thought to play an important role in the transformation of the vertical flux of particles (Alldredge, 2005).

During the MARECO cruise in June-July 2004 the Underwater Video Profiler (UVP) was used to quantify the midwater macrozooplankton along the northern portion of the Mid-Atlantic Ridge. In this part of the North Atlantic Ocean the surface circulation is characterized by two large gyres, the subpolar and subtropical. The Sub Polar Front (SPF) is the boundary between the northerly cool and less saline waters and the southerly warm and saline waters (Rossby, 1999). The composition and abundance of macrozooplankton communities showed coherence with the distribution of water masses (Stemmann et al., 2007). The SPF appears to be a major boundary for the macrozooplankton even in the mesopelagic layers. The largest concentrations of several groups of macrozooplankton (mostly medusae, ctenophores, appendicularians, sarcodines) were observed in the mesopelagic deeper than 300 m depth at all sites. The objective of this work is to assess whether there is a link between the vertical pattern of appendicularians and particles in the different provinces of the North Atlantic.

Methods

Sampling sites

The vertical distribution of major groups of macrozooplankton and particles (>60µm) along the Mid-Atlantic Ridge (from 59°58N, 25°53W to 41°29N, 28°19W, Figure 1) was observed at 39 stations with the UVP (Figure 1). The details of the sampling and the methodology used to assess the spatial pattern of the macrozooplankton and particles can be found in Stemmann et al., (2007). Only the main points are given here. Identified organisms (of 1 to 10 cm in size) were sorted into 12 groups of zooplankton that could be analysed quantitatively. Twelve relatively large (> 1 cm) groups were selected from the recorded images: sarcodines (with two sub-groups), crustaceans (excluding copepods), chaetognaths, ctenophores (with two sub-groups cydippids and lobates), siphonophores, medusae (with three subgroups *Aeginura grimaldii, Aglantha* spp. and all other medusae), appendicularians, and thaliaceans. The particles were counted and sized by the automatic system. The area in pixel of each particle was converted into Equivalent Spherical Diameter in metric units from which an equivalent spherical volume was calculated assuming that the particles are plain spheres.

The 39 stations could be lumped into four regions that had similar hydrological characteristics and also similar composition in the mesopelagic community (Stemmann et al., 2007 and Stemmann et al., submitted). These groups were named after the dominant water mass in the upper 1000 m. Three of the groups had TS characteristics of defined water masses from the area (Sub-Arctic Intermediate Water, Modified North Atlantic Water, North Atlantic Central Water) while two showed modified properties from the North Atlantic Central Water. The Sub-Arctic Intermediate Water (SAIW, stations 8 to 22 and 64 to 74) had the lowest temperature and salinity within the 100-1000 m, whereas the highest temperature and salinity occurred in the North Atlantic Central Water (NACW, stations 28 to 52). TS characteristics were intermediate in the upper 1000 m in the Modified North Atlantic Water (MNAW, stations, 2 to 6). Two groups of stations with TS characteristics modified from the NACW are referred as NACWf (North Atlantic Central Water front, 24, 26 and 56 to 62). The first one was located in the front and the second one in an eddy North of the front (Stemmann et al., 2007).

Results and discussion

The cruise was conducted at the end of the North Atlantic spring bloom which started in April during year 2004 (Stemmann et al., 2007). Therefore, the cruise took place at a time when a large pulse of organic matter was likely to have sunk into the mesopelagic layer of the whole area. Thus it is possible that the macrozooplankton concentrations recorded by the UVP may represent yearly maximal concentrations. However this seasonal trend may be modified by local trophic conditions in each water mass. For example, the upper layers of the NACW, were oligotrophic showing the lowest nitrate concentrations and Chl *a* biomass (nitrate <3 µmol kg^{-1} in the mixed layer and up to 42 mg Chl *a* m^{-2} in the upper 200 m depth). By contrast, the MNAW and SAIW had more mesotrophic conditions (nitrate >7 µmol kg^{-1} in the mixed layer and Chl *a* up to 100 mg m^{-2}). The lower observed abundances of almost all groups in the NACW may have been a consequence of this lower productivity and vertical export of the NACW region. The detail analysis of the results is given in Stemmann et al., (2007) and this paper will focus on the results concerning the vertical profiles of appendicularians and particles.

The numerically dominant groups were crustaceans (26%) followed by the medusae (20% pooling Med., Agl. and Gri.), appendicularians (17%) and chaetognaths (11%) (Figure 2). Among the four dominant groups, only appendicularians and chaetognaths were consistently numerous at all stations. Their size ranged from 1 cm to approximately 5 cm in diameter. Appendicularians were the third most abundant group of soft-bodied zooplankton and they were usually observed deeper than 300 m (Figure 3). However, an epipelagic population was found in the NACW region. Their deep maximum concentration (up to 58 ind. $100m^{-3}$) occurred between 400 and 500 m depth in the NACWf region. The abundances of appendicularians are higher (within one order of magnitude) in our study compared to the MIR submersible observations in the same region (Vinogradov *et al.*, 2005; Vinogradov *et al.*, 2000). The lower estimates from the MIR are probably due the fact that the UVP is better suited for detecting smaller (<5 cm) organisms.

Particles vertical profiles showed that the biovolume of particles (60µ<ESD<1mm) generally decreased with depth rapidly down to 150 m (NACW) and 300-400 m (the other regions) (Figure 4). A midwater peak of small particles is observed in the MNAW and SAIW regions. In contrast, the decrease in biovolume with depth of the large particles (1-5mm) is smoother and an increase in concentrations with depth below 300-400 m is also observed clearly in the SAIW and NACWf region. This increase in large particle biovolume is associated with an increase in appendicularians abundance. Moreover, in the MNAW region a peak in the biovolume of large particles (400-500m) is clearly associated with a peak in appendicularians concentrations. The only region that does not show an increase in large particle biovolume is the NACW. This region had the lowest concentration of appendicularians and particles. The lack of relationship in the NACW may result from the lower concentration of organisms that may not have impacted the size spectra. Appendicularian are know to be efficient in the aggregation of particles into larger aggregates (>1mm) than can sink rapidly to the deep ocean (Alldredge, 2005; Robison et al., 2005). Therefore, the observed close vertical association between the large particles and the appendicularians could result from the small particles aggregation by appendicularians into feces or discarded houses. These small particles may not be measured by the UVP because their size is much smaller than the size of particles detected by the UVP (60µm<<1mm). Association between appendicularians and the size spectra of particles had not been previously observed and suggest that these organisms maybe important players in the transformation of particle flux the main carrier of the Particulate Organic Carbon (POC) to the deep sea.

The potentially great contribution of appendicularians to POC flux transformation means that the relatively scant attention that has been paid to them needs to be redressed for a better understanding of their contribution on the global scale. Imaging systems such as the UVP can provide the necessary information to assess the different components that act on the flux in the mesopelagic layer.

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Bibliography

Alldredge, A.L., 2005. The contribution of discarded appendicularian houses to the flux of particulate organic carbon from oceanic surface waters. In: Gorsky, G. (Ed.), Response of Marine Ecosystems to Global Change: Ecological Impact of Appendicularians. GB Science Publishers-Editions Scientifiques, Paris, pp. 309–326.

Dagg, M., 1993. Sinking particles as a possible source of nutrition for the large calanoid copepod *Neocalanus cristatus* in the Subarctic Pacific Ocean. Deep-Sea Research Part I 40 (7), 1431-1445.

Fowler, S.W., Small, L.F., La Rosa, J., 1991. Seasonal particulate carbon flux in the coastal northwestern Mediterranean Sea, and the role of zooplankton fecal matter. Oceanologica Acta 14, 77-85.

Lampitt, R.S., Wishner, K.F., Turley, C.M., Angel, M.V., 1993 Marine snow studies in the Northeast Atlantic Ocean: Distribution, composition and role as a food source for migrating plankton. Marine Biology 116 (4), 689-702.

Robison, B.H., 2004. Deep pelagic biology. Journal of Experimental Marine Biology and Ecology 300 (1-2), 253-272.

Robison, B.H., K.R. Reisenbichler, and R.E. Sherlock. 2005. Giant larvacean houses: rapid carbon transport to the sea floor. Science 308:1609-1611.

Rossby, T., 1999. On gyre interactions. Deep-Sea Research Part II 46, 139-164.

Steinberg, D.K., Silver, M.W., Pilskaln, C.H., 1997. Role of mesopelagic zooplankton in the community metabolism of giant larvacean house detritus in Monterey Bay, California, USA. Marine Ecology Progress Series 147 (1-3), 167-179.

Stemmann, L., Jackson, G.A., Gorsky, G., 2004. A vertical model of particle size distributions and fluxes in the midwater column that includes biological and physical processes - Part II: application to a three-year survey in the NW Mediterranean Sea. Deep-Sea Research Part I 51 (7), 885-908.

Stemmann, L., Hosia, H., Youngbluth, M.J.A., Søiland, H., Picheral, M., Gorsky, G. (accepted) Vertical distribution (0-1000 m) of gelatinous zooplankton in different hydrological regions along the Mid Atlantic ridge in the North Atlantic. Deep Sea Research Part II

Stemmann, L., Robert, K., Hosia A., Picheral, M., Paterson, H., Youngbluth, M, Ibanez, F.,Guidi, L. and Gorsky G (submited to ECS Journal of Marine Science). Global biogeography of fragile macrozooplankton in the upper 100-1000 m depth inferred from the Underwater Video Profiler.

Vinogradov, G.M., 2000. Vertical distribution of large planktonic animals in the cold waters of the Labrador current north of the Gulf Stream Frontal Zone. Oceanology 40 (4), 525-531.

Vinogradov, G.M., 2005. Vertical distribution of macroplankton at the Charlie-Gibbs Fracture Zone (North Atlantic), as observed from the manned submersible "Mir-1". Marine Biology 146 (2), 325-331.

Wassmann, P., Ypma, J.E., Tselepides, A., 2000. Vertical flux of faecal pellets and microplankton on the shelf of the oligotrophic Cretan Sea (NE Mediterranean Sea) [Review]. Progress in Oceanography 46 (2-4), 241-258.

Wishner, K.F., Gowing, M.M., Gelfman, C., 1998. Mesozooplankton biomass in the upper 1000 m in the Arabian Sea: overall seasonal and geographic patterns, and relationship to oxygen gradients. Deep-Sea Research Part II 45 (10-11), 2405-2432.

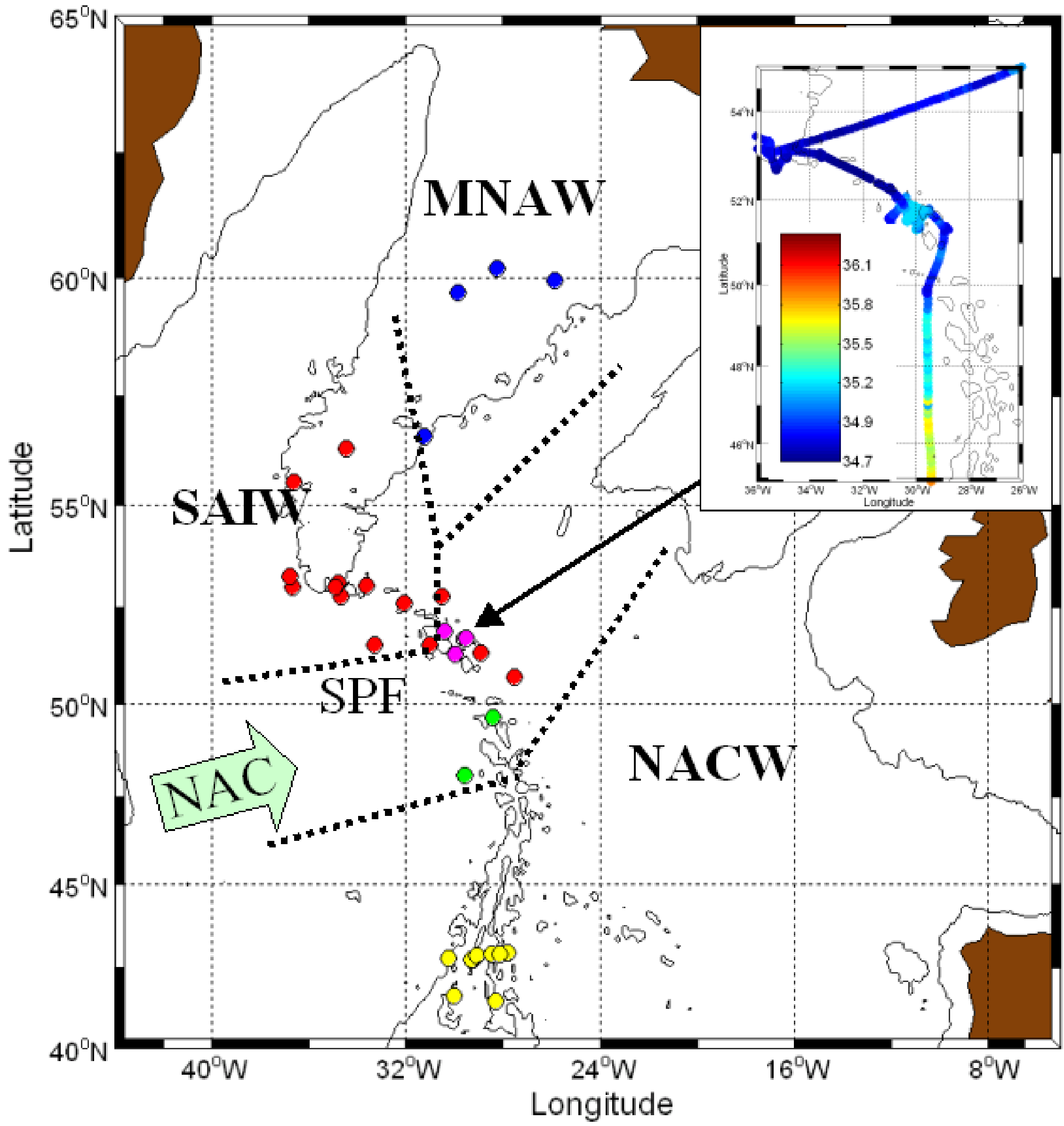

Figure 1: The area sampled during the MARECO cruise. The North Atlantic Current (NAC) is represented by the large green arrow. The stations in green and magenta in the Sub Polar Front are labeled NACWf in the text. The sea surface salinity in the SPF (=displayed in the box in the upper right of the map) shows the position of the eddy during LEG2. The regions where the SubArctic Intermediate Water (SAIW) and Modified North Atlantic Water (MNAW) were present are also labeled.

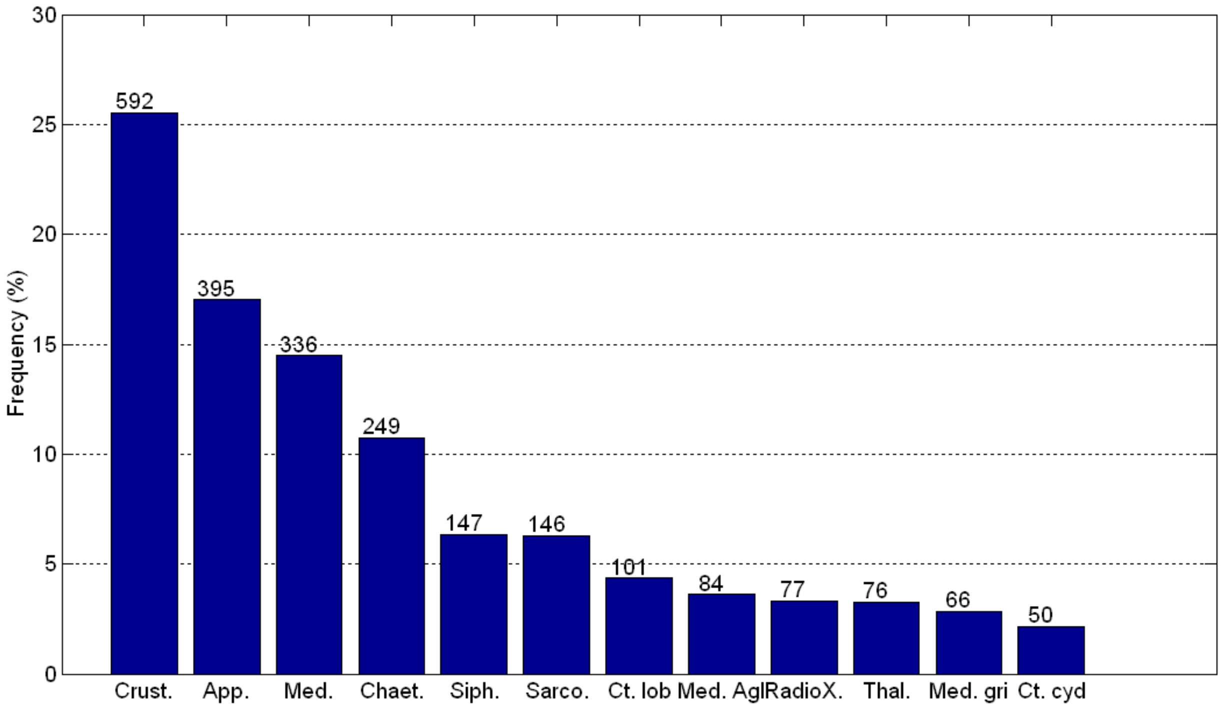

Figure 2: Frequency of occurrence over the whole area for the different groups of zooplankton. The total number of individuals per taxonomic group is reported over each column

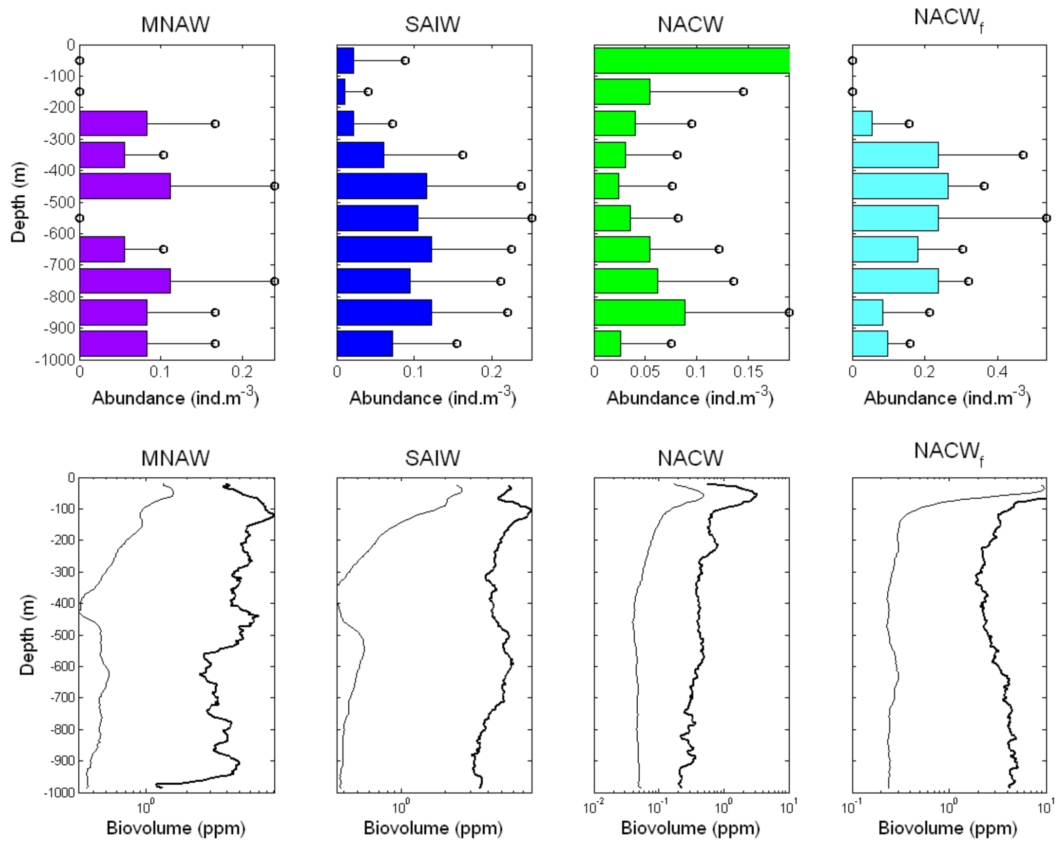

Figure 3: Vertical distribution of appendicularians (upper panel, bars are mean abundance and the stems are the standard deviation) and particles (lower panel, 60µm <ESD<1 mm thin line and 1<<5mm bold line) in the four oceanic regions.