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Trophic interaction of invertebrate zooplankton on either side of the Charlie Gibbs Fracture Zone/Subpolar Front of the Mid-Atlantic Ridge

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ABSTRACT

Trophic relationships and vertical distribution patterns of dominant mesozooplankton (2–20 mm) and macrozooplankton (>20 mm) invertebrates (Euphausiacea, Copepoda, Decapoda, Amphipoda, Thecosomata and Lophogastrida) were investigated within the epi- and meso-pelagic zone (0–200 and 200–800 m depth), north (54° N) and south (49° N) of the Subpolar Front (SPF) on the Mid-Atlantic Ridge (MAR). Dietary relationships were explored using stable isotope ratios of nitrogen and carbon, and fatty acid trophic markers (FATM). Individuals from the southern stations (~49° N) had higher concentrations of the dinoflagellate FATM (22:6(n-3)), and individuals from northern stations had higher concentration in *Calanus* sp. and storage FATMs (20:1(n-9) and 22:1(n-9)). Energy pathways on either side of the SPF showed retention of $\delta^{13}C$ differences (as measured in POM) in bathypelagic species. Observations of FATM levels and abundance patterns are consistent with present theories pertaining to primary production patterns at the base of the food chain, which states that the peak of the production is higher in the northern sector than in the south.

1. Introduction

Open water zooplankton play a key role in the transfer of energy to the deep sea, forming a trophic and migratory link between the surface productivity and deeper predatory fauna. Food is transferred to the deep sea in the form of detritus, faecal pellets and sinking dead organisms (Schnack-Schiel and Isla, 2005), but also through trophic linkages via vertically migrating organisms (Angel, 1997). Daily migrating zooplankton come into close proximity with predatory demersal nekton, particularly at seamounts and ridges (Pitcher, 2008; Rogers, 1994). Some taxa like copepods and euphausiids form key links in oceanic pelagic food webs, exerting both top–down and bottom–up control, on phytoplankton and higher trophic levels. In oceanic and pelagic systems interactions between zooplankton and demersal fish stocks are mediated by a trophic spectrum of macrozooplankton (>20 mm).

Seamounts around mid-ocean ridges have experienced boom and bust exploitation (Pitcher, 2008) and, therefore, broad ecosystem knowledge is becoming increasingly important in order to undertake ecosystem-based fishery management. There is a need to understand and describe the trophodynamics of the lower end of open ocean food chains.

The Mid-Atlantic Ridge (MAR) is a major shallow subarea of the central Atlantic with peak depths rising to within 500 m from the surface, which is probably sufficiently shallow to affect distribution patterns of meso- and bathypelagic organisms. The Charlie Gibbs Fracture Zone (CGFZ) at the Subpolar Front (SPF) intersects the MAR at 52° N and lies at the junction of three different oceanic provinces (North Atlantic Drift Province, Atlantic Arctic Province, Atlantic Subarctic Province, NADR, ARCT, SARC respectively, see Longhurst, 1998) and between two sectors of different patterns of primary productivity. The Subarctic waters north of the SPF over the Reykjanes ridge are characteristic of high latitude waters: low temperature (<8 °C), high salinity (>35), and highly productive during the spring and summer months (80 g C.m^{-2}.month^{-1}; Longhurst, 1998). To the south of the SPF, waters are more typical of temperate latitude, with a somewhat lower production peak (<50 g C.m^{-2}.month^{-1}; Longhurst, 1998) and sustained production throughout the summer months. These two sectors have been shown to harbour different communities of primary consumers (Falkenhaug et al., 2007), but the influence of these production patterns on higher trophic levels residing at greater depths are less clear and the extent to which primary production regimes influence benthopelagic coupling in general is currently unknown.

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Trophic interactions among fauna associated with the bottom topography and 'true pelagics' (animal that do not interact with the seafloor) can be investigated using a combination of techniques, such as stomach content analysis (Kaartvedt et al., 2002), lipid analysis (Falk-Petersen et al., 1990, 2000), and carbon and nitrogen stable isotope analysis (SI, Schmidt et al., 2003). Studies utilising these techniques have focussed on the high (pelagic and demersal fish, see Hoffman and Sutton, 2010, V. Carmo work in progress), and low- (mesozooplankton, Petursdottir et al., 2010) trophic levels of the MAR, but only Petursdottir et al. (2010) has tried to establish trophic connections across multiple trophic levels. Their study was restricted to the shallow Reykjanes ridge-section. These studies suggest that the enhanced benthic boundary layer (BBL) nektic biomass may be transferred through trophic levels by at least two pathways (Petursdottir et al., 2008) with *Calanus* sp. an important component in the diet of *Sergestes* sp. and the myctophiid *Benthosema glaciale*, and *Meganyctiphanes norvegica* a dominant source of food for the red fish *Sebastes mentella*. However, mechanisms serving to maintain this enhanced biomass across the latitudinal extend of the MAR, compared to open water habitats, remain largely unexplored.

Fatty Acid (FA) and stable isotope analyses provide assimilated, time-integrated information on the food source and relative trophic position of an organism within a food web. Few species synthesise *de-novo* fatty acids, and Fatty Acid Trophic Markers (FATMs) accumulate in grazers and predators over time. Identifying FATMs, allows energy transfer and predator prey relationship to be traced through the food chain: for example the FATM 20:5 (n-3), 16:1(n-7), and C16 polyunsaturated fatty acids (PUFA) for diatoms; C18 PUFAs for dinoflagellates; and the FATMs, 20:1 (n-9) and 22:1(n-11) for *Calanus* copepods (Dalsgaard et al., 2003). Their relative ratios provide an indication of long-term trophic exchange (Kattner et al., 1994), enabling the identification of lipid source, to taxonomic groups such as diatoms, dinoflagellates and calanoid copepods. Stable isotope ratios of carbon (^{12}C:^{13}C expressed as $\delta^{13}C$) and nitrogen (^{14}N:^{15}N expressed as $\delta^{15}N$) provide a complementary tool to FA. Both carbon and nitrogen stable isotopes show a stepwise enrichment in the heavier isotope, ^{13}C and ^{15}N, as a result of isotopic fractionation or discrimination during metabolic processes. $\delta^{15}N$ increases between 3–5‰ (Hobson and Welch, 1992; Hobson et al., 1995) from energy source to the consumer and is used as a proxy to determine the relative trophic position of a species or individual in its ecosystem (Jardine et al., 2003). Stable carbon isotopes provide information on the source of the primary productivity, for example pelagic CO_2 sources are depleted in ^{13}C relative to ^{12}C compared to benthic CO_2 sources, see France (1995) and Hecky and Hesslein (1995). Particulate organic matter (POM) $\delta^{13}C$ and $\delta^{15}N$ values vary geographically (Waser et al., 2000) and this variability is transmitted through the food web, which needs to be accounted for when comparing patterns in trophodynamics between regions.

The objectives of this study were twofold:

1) To describe vertical patterns of the invertebrate macrozooplanktic (drifters) and micronektic (swimmers) distribution in the epi-and mesopelagic (0–800 m) over the MAR, and compare faunal composition at two sectors with hypothesized different primary production patterns.
2) Using FA and SI analysis, to investigate trophic interactions at the species and community level with respect to depth and geographic differences in faunal abundances and describe the role of different primary production sources on trophic interaction in the different zones of the MAR.

2. Materials and methods

2.1. Field sampling

2.1.1. Zooplankton community and Particulate Organic Matter

Invertebrate mesozooplankton (>2 mm) and macrozooplankton (>20 mm) were collected at sea from two locations on either side of the SPF (Fig. 1), using a multiple Rectangular Mid-Water trawl (RMT1 + 8 M, Roe and Shale, 1979), during NERC (Natural Environmental Research Council)-funded ECOMAR (Ecosystems of the Mid-Atlantic Ridge at the Sub-Polar Front and Charlie-Gibbs Fracture Zone) consortium cruises on board the R.R.S *James Cook* cruises to the MAR in 2007 and 2009 (Fig. 1 and Table 1).

Only the catches from the RMT8 net were considered in this study (4.5 mm mesh size). For the estimation of faunal abundance, the bulk of the material was sorted to genera or species at sea, and preserved in borax-buffered formaldehyde 4% (Steedman, 1976). Upon return to the lab, samples were transferred to 70% ethanol for preservation and further taxonomic analysis. Dominant zooplankton taxa were identified to the lowest possible taxon using morphology-based

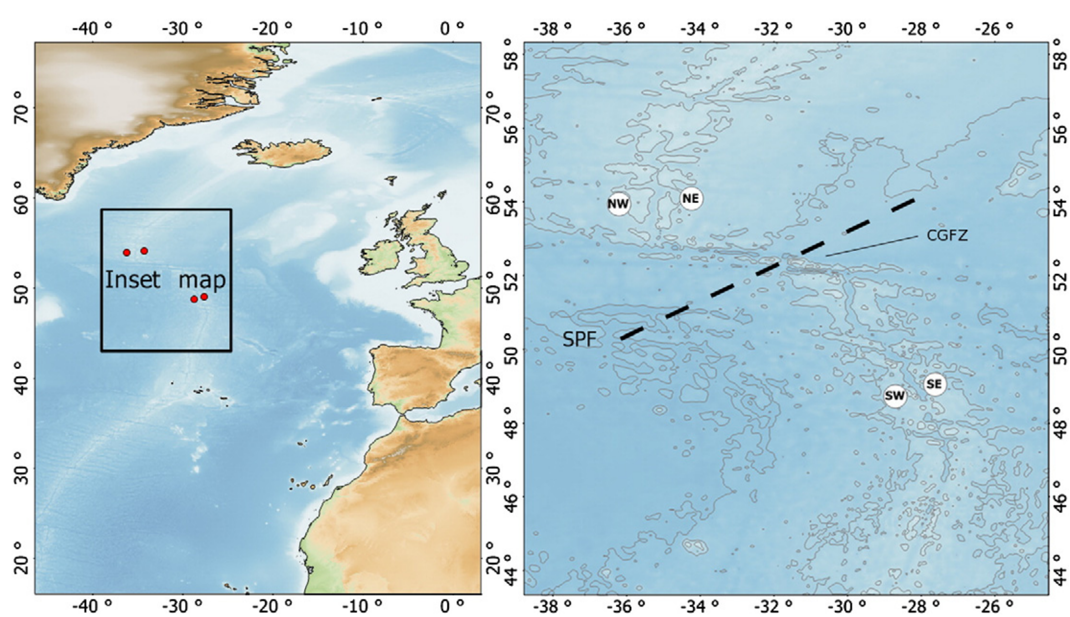

Fig. 1. Sampling locations on the Mid-Atlantic-Ridge during the JC011 (2007) and JC037 cruise (2009). Only the SW and NE stations were sampled in 2007 (see Table 1). Seabed depth at all stations was 2500 m. The 500, 1000, 2000, 3000, and 4000 m isobaths are shown.