The mesozooplankton community of the Belgian shelf (North Sea)

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ABSTRACT

This manuscript presents the mesozooplankton community structure and its spatial and temporal variabilities in the Belgian part of the North Sea (BPNS), a first thorough study on this topic in nearly 40 years. Monthly sampling campaigns at ten stations in the BPNS in 2009 and 2010 yielded a total of 137 mesozooplankton taxa (46 holoplanktonic, 50 meroplanktonic and 41 tychoplanktonic), of which nine species had never been reported in the area. Smaller neritic copepods, especially *Temora longicornis* and *Acartia clausi*, were present in all samples and dominated zooplankton densities (66%), together with the appendicularian *Oikopleura dioica* (10%). They were joined by high numbers of meroplanktonic echinoderm larvae (9%) in spring and summer. Based on diversity alone, the mesozooplankton could be typified as one neritic zooplankton community, due to the ubiquitous presence in time and space of the dominant copepods. Yet, these neritic species were often joined by low numbers of oceanic species that are occasionally imported with the inflow of Atlantic oceanic water in the BPNS. Based on a combination of abundance and diversity, our results indicate distinct seasonal and spatial distribution patterns in the mesozooplankton. Months with highest average densities were May, June and July, lowest densities were noted in December and January. Only limited long-term zooplankton data are available for the BPNS from the Continuous Plankton Recorder surveys or the long-term monitoring stations in the vicinity of our research area. However, our data suggest that nowadays zooplankton species appear earlier in the BPNS, comparable with other areas in the North Sea. Densities varied between 150 and 15,000 ind.m^{-3}, and averaged highest at midshore stations, then nearshore and offshore. This is partially comparable with the spatial patterns recorded for other ecosystem components, such as demersal fish, epibenthos and macrobenthos, of which densities peak in a stretch almost parallel to but some miles away from the coastline in the BPNS.

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1. Introduction

The vast majority of fish species have a pelagic larval phase (Russell, 1976), which depends on the zooplankton as an important food source. For this reason, and because of their sheer abundance, high diversity and vital ecosystem functions (Richardson, 2008), zooplankton communities are crucial in the marine food web. Since zooplankton can be considered as the major grazers in ocean food webs, they provide the principal energy pathway from primary producers to consumers at higher trophic levels, including fish and marine mammals (Mauchline, 1998; Richardson, 2008). In the southern North Sea, small calanoid copepods dominate the zooplankton, up to 84% of the spring and summer abundance (Krause et al., 1995). Copepods fulfill a key role in marine food webs, not only transferring energy to higher trophic levels, but also to the bottom through sedimentation of fecal pellets (Nielsen et al., 1993).

Zooplanktonic organisms also help to shape the extent of climate change through carbon fixation via the biological pump, but are, paradoxically, themselves very susceptible to a changing climate

(Richardson, 2008). In the North Sea and the English Channel, temperature has increased by 1.1 °C since 1962 (Wiltshire and Manly, 2004), leading to a northward displacement of marine organisms and match–mismatches between predator and prey (Cushing, 1990; Hays et al., 2005; Southward et al., 1995). The replacement of the cold water *Calanus finmarchicus* species assemblage in the North Sea by the warm water *Calanus helgolandicus* dominated copepod assemblage with lower biomass and smaller species, is a classic example of the severe consequences of a warming climate on marine ecosystems (Richardson, 2008).

In a healthy marine ecosystem, herbivorous zooplankton can control natural phytoplankton blooms and keep the system in balance (Rousseau et al., 2006). However, the southern North Sea, including the Belgian part of the North Sea (BPNS), is known as a eutrophicated ecosystem, due to anthropogenically induced nutrient inputs through the discharge of the major western European rivers (Lancelot et al., 1998; Rousseau et al., 2006). The unbalanced nutrient environment is characterized by an excess of nitrate over silicate and phosphate, leading to spring algal blooms, with a major and sudden change in phytoplankton dominance from diatoms to the flagellates *Phaeocystis globosa* and *Noctiluca scintillans* (Lancelot, 1995; Peperzak et al., 1998; Vasas et al., 2007). Because *P. globosa* is resistant to grazing, it is

considered a trophic dead end in the planktonic food chain (Daro et al., 2006; Nejstgaard et al., 2007). This may lead to a reduced abundance of bottom-up controllers, which might have far-reaching and long-term effects throughout the food web (Lancelot et al., 2007). It seems to be an intrinsic property of temperate pelagic ecosystems strongly affected by human activities, to stimulate the microbial network while inhibiting the higher trophic levels, an effect that is exacerbated by overfishing of planktivorous fish (Vasas et al., 2007).

Considering the climate change with concomitant biogeographical and phenological shifts in the distribution of planktonic species, and the vital importance of plankton in the marine food web, an update of zooplankton community dynamics in the BPNS, positioned in the transitional region between the Atlantic Ocean and the North Sea, is certainly in place.

For the BPNS few historic studies on zooplankton are available. The oldest known marine zooplankton samples date from the early 20th century (Gilson collection, discussed in Van Loen and Houziaux, 2002). However, there was little to nothing published about the zooplankton species in these samples, as the main focus was on benthic organisms. Daro (1974; 1985a,b) studied diurnal zooplankton behavior in the Sluice dock (Ostend port) and at a station in the BPNS (25 m depth), where she observed vertical migration of the calanoid copepods *Temora longicornis* and *Pseudocalanus elongatus* during the spring phytoplankton bloom. Van Meel (1975) was the first to report a zooplankton species list from the BPNS and adjacent waters. The data in most of these older (benchmark) studies are qualitative rather than quantitative, hence they serve best for presence–absence comparisons (see Van Ginderdeuren et al., 2012a). More recent zooplanktonic research in Belgium focused on hyperbenthic species (Dewicke et al., 2003) or on a limited number of zooplankton species, like the work on floating seaweed inhabitants by Vandendriessche et al. (2006) and on *Lanice conchilega* larvae by Van Hoey (2006). Several studies investigated the calanoid copepod interactions with the harmful algae *P. globosa* (e.g. Antajan, 2004; Daro et al., 2006; Gasparini et al., 2000; Rousseau et al., 2006). M'harzi et al. (1998) investigated zooplankton from the BPNS, but used different gears at one fixed depth in only one month, which makes it difficult to compare results. Zooplankton dynamics in the Westerschelde estuary (the Netherlands), at the border of the BPNS, received considerably more attention (e.g. Appeltans et al., 2003; Azémar et al., 2004; Bakker and De Pauw, 1975; Maes et al., 2002; Soetaert and Van Rijswijk, 1993; Tackx et al., 2004; Tackx et al., 2005), but up till now, recent data on the marine part of the BPNS remained extremely scarce.

Abroad, a vast amount of North Sea zooplankton data have been gathered by the Continuous Plankton Recorder (CPR) surveys (SAHFOS, conducted since the 1940s). The CPR covers a large area but faces several impracticalities: only a limited part of the North Sea is studied on a yearly basis, only the surface water layers are sampled, and the device has a very narrow entrance aperture ($1.6 \, cm^2$), which makes it less likely to catch big and faster zooplankton species (Haddock, 2008). Moreover, there is a clear lack of CPR samples from the English Channel and the southern North Sea. Also no monthly monitoring station exists in the vicinity of Belgian waters, which could allow for a detailed temporal analysis (O'Brien et al. 2011). The nearest zooplankton monitoring stations are the Plymouth L4 survey area in the western part of the English channel and Helgoland roads in the German bight (O'Brien et al., 2011).

The aims of this manuscript are: (1) to characterize the mesozoo-planktonic (>200 μm) community structure in the BPNS on the basis of zooplankton species composition, abundance, species richness and habitat preferences; (2) to investigate whether calanoid copepods dominate the food web, and which patterns in temporal and spatial patterns can be noted in the zooplankton community structure; and (3) to compare the zooplankton community structure with plankton data from other parts of the North Sea and the English Channel and with the few available Belgian 'historic' data.

2. Materials and methods

2.1. Study area

This study covers the entire Belgian Exclusive Economic Zone (ca. $3600 \, km^2$), referred to as the Belgian part of the North Sea (BPNS), and is situated in the Southern Bight of the North Sea. The BPNS has a maximum seaward width of 87 km and is bounded by a 67 km long sandy coastline, bordered eastwards by the Westerschelde estuary (Degraer et al., 2003). The prevailing marine currents convey saline Atlantic water in a NE direction through the Channel towards the BPNS, where it meets the SW oriented Westerschelde outflow (Howarth, 2001; Nihoul and Hecq, 1984). The current regime is macro-tidal (tidal amplitude averages 4 m) and keeps the water column (with an average depth of 30 m) well mixed (MUMM, 1996).

The BPNS seabed contains several sandbank systems with a high morphological and sedimentological diversity, resulting in different benthic communities (Degraer et al., 1999; Van Hoey et al., 2004), producing planktonic larvae (Van Ginderdeuren et al., 2012a) and subsequently influencing the pelagic ecosystem via benthic–pelagic coupling (Provoost et al., 2013).

2.2. Data origin

Sampling was carried out monthly in 2009 and 2010 with RV Zeeleeuw (apart from January and February 2010 due to RV main-tenance) at up to ten monitoring stations covering the entire BPNS, positioned along a nearshore–midshore–offshore axis (Fig. 1). A WP2 zooplankton net (57 cm diameter, 200 μm mesh size; Fraser, 1968) fitted with flow meter (Smith et al., 1968) was towed in an oblique haul from bottom to surface at each station. Samples were fixed and preserved in a 4% formaldehyde solution. A CTD (Seabird 19plusV2) cast was carried out at every station for measuring depth, temperature and salinity. Chlorophyll *a* data were attained via MODIS and MER satellite imaging systems (Vanhellemont et al., 2011). A total of 112 samples (53 nearshore, 30 midshore, 29 offshore; 74 in 2009, 38 in 2010), taken in salinity ranges from 30 to 35 and temperature ranges from 2 to 21 °C, was worked out. Data were added to the database of the Bio-Environmental Research unit (ILVO).

In the lab, taxa were identified to species level when possible, using optical microscope and stereomicroscope equipment. Animals too big or too rare to subsample were initially sorted from the catch in a general sweep. Then subsequent subsamples (small volumes) were taken from the remainder of the sample, for counting and identification of abundant zooplankton species (often present in thousands). When at least 100 calanoid copepods were identified, also that last subsample was further worked out completely (van Guelpen et al., 1982). As such, subsample densities could then be converted to total abundances for every species. Calanoid copepods were identified to species level and staged as adults (sexed) or copepodites. Copepodites of *Centropages hamatus* were not distinguished from those of *Centropages typicus*, nor those of *Paracalanus parvus* from *P. elongatus*.

All sample data yielded an original set of 145 taxa. After exclusion of species that were not sampled quantitatively (e.g. benthic species) and lumping taxa due to inconsistent identification (e.g. Caridea and Polychaeta larvae), a set of 137 taxa (further referred to as 'species') was used for multivariate analyses. The different taxa were further classified according to their lifestyle as holoplanktonic (organisms spending their entire life as plankton in the water column, e.g. calanoid copepods), meroplanktonic (early life stages, mainly from larger animals, that spend part of their life as plankters, e.g. decapod larvae) and tychoplanktonic (species that are occasionally carried into the water column, e.g. benthic species and hyperbenthic groups such as Mysida and Cumacea).