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Changes of benthic fauna in the Kattegat – An indication of climate change at mid-latitudes?

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ABSTRACT

Several predictions point to changes in the marine benthic macrofauna associated with climate change, but so far only a few and minor changes have been reported. This study relates observed changes in the species composition to climate change by looking on the past decades in the Kattegat between Denmark and Sweden. A reduction of the total number species and a reduction of species with a northern range parallel to an increase of species with a southern range have been observed. The most likely explanation of the changes is the increase in temperature of the bottom water. Increased temperature could change the species distributions but also decrease primary production which impacts recruitment and growth. Hypoxia and bottom trawling could also act synergistic in this process. A sparse occurrence of previously encountered Arctic-Boreal species and critical foundation species, which gives the area its special character, suggests a change in biodiversity and might therefore be designated as early warning signals of a warmer climate. The northern fauna below the halocline with limited capacity of dispersal and low reproduction potential, can be considered as sensitive with low adaptive capacity to climate change. Therefore, not only tropical and high-latitude species, but also benthos on deep bottoms at mid-latitudes, could be vulnerable to warming. As many species live at the edge of their range in the Kattegat, and also are dependent of distant recruitment, large scale changes will probably be detected here at an early stage. It is important to protect relatively undisturbed reference areas in the Kattegat for future studies, but also for preserving a large number of ecosystem services, biotopes, habitats, and fish species.
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1. Introduction

1.1. The aim of this study

This study aimed to identify long term changes of species composition related to geographic area of distribution with special emphasis on climate change. This is especially important as a rise in the bottom water temperature has been recorded in later years. Therefore, the faunal response to changes in bottom water temperatures was studied in a 24 year perspective. Trawling could result in changes of area of distribution of benthos (Hiddink et al., 2015), but the impact is not selective to northern or southern species. Dawson et al. (2011) points to three important factors considering vulnerability of climate change, exposure, sensitivity and adaptive capacity. An increased temperature also means that the fauna can be impacted both by hypoxia and high temperatures and these factors in combination.

1.2. Background

Observations of species responses that have been linked to anthropogenic climate change are widespread, but are still lacking for some taxonomic groups e.g., phytoplankton, benthic invertebrates, marine mammals (Poloczanska et al., 2016). However, several studies point to large changes in the benthic macrofauna associated with climate change (Thomas et al., 2004; Hiscock et al., 2004; Reiss et al., 2011; Birchenough et al., 2015). However, so far only relatively minor changes have been presented (Barry et al., 1995; Southward et al., 2004; Mieszkowska et al., 2006; Beukema et al., 2009; Hiddink et al., 2015). Changes in the fauna could also be related to the variability in the North Atlantic Oscillation climate index (Tunberg and Nelson, 1998; Kröncke et al., 1998, 2011).

Tropical and high-latitude species are considered particularly vulnerable to warming (Tewksbury et al., 2008). However, Meyer et al. (2016) report long-term variability of species number and abundance of epibenthos and demersal fish at a shallow site in the North Sea that could be related to climate impact. Singer et al.

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(2017) predicted significant changes in the range sizes and occurrences of most modelled species at the same site until the mid 21st century.

1.3. Study area

The Kattegat is a shallow sea area between Denmark and Sweden, situated on the border between the Skagerrak and the Baltic. The surface water is largely affected by the Baltic surface current from the south via the Sound and the Belt Sea with a salinity of about 10–15. Marine conditions are found at bottoms below 25 m depth with a salinity of about 30. A strong halocline at 10–20 m depth moves vertically, largely dependent on the rate of inflow from the Baltic. The strong stratification of the water column prevents vertical water exchange, especially in the southern part. Here, bottoms below the halocline are occasionally stressed by low oxygen concentrations in the autumn. The special hydrographic conditions creates the prerequisites for a diverse benthic macrofauna with a relative high share of Arctic-Boreal species (Brattström, 1941).

1.4. The northern fauna of the Kattegat

Brattström (1941) showed that the echinoderm fauna in the 1930s to a large part (approx. 20–30%) consisted of Arctic-Boreal species in the southern Kattegat and the adjacent Sound. The echinoderm fauna were then dominated by Mediterranean-Boreal and widely distributed species (about 60%). The Brattström (1941) description of the fauna still holds. The rather high Arctic-Boreal fauna element probably depends on the lower temperatures and narrower temperature range compared to adjacent sea areas. There are nowadays several examples of cold water species, common in the Arctic region, that are almost only abundant in the southern Kattegat and the Sound on the Swedish west coast, i.e. the bivalves *Musculus niger* and *Macoma calcarea*, and the gastropod *Euspira pallida*. As an example, *Macoma calcarea* can only withstand temperatures less than 11 °C long term. All three species are on the national red-list (http://www.artdatabanken.se/en/the-red-list/) and the two last on the Helsinki Commission (HELCOM) red-list of Baltic species (http://www.helcom.fi/baltic-sea-trends/biodiversity/red-list-of-species).

Moreover, the special temperature conditions in the deep water could be one of the explanations of recent highly diverse *Modiolus* beds and past *Haploops*-communities with a high share of Arctic-Boreal species, important for fishing. *Modiolus modiolus, Haploops tubicola* and *Haploops tenuis* are on the national and HELCOM red-list. *Modiolus* beds are also on the Oslo and Paris Conventions (OSPAR) list of threatened and/or declining species and habitats (http://jncc.defra.gov.uk/pdf/0806e_OSPAR%20List%20species%20and%20habitats.pdf). Local temperature regimes plays a major role for several species. For example, for *Modiolus modiolus* it impacts the interacting processes of gametogenesis and spawning (Brown, 1984). This species does not tolerate large temperature changes (Davenport and Kjorsvik, 1982).

The Kattegat holds several high salinity demanding, more or less isolated, Arctic-Boreal species populations below the halocline. This depends on the relatively stable salinity conditions and on the special temperature conditions on the border of the Baltic, one of the largest brackish waters.

1.5. Structuring factors

Several factors structure the benthic macrofauna, both abiotic and biotic. Among abiotic factors temperature and depth are probably most important (Reiss et al., 2011). Rosenberg (1995) suggested hydrodynamic processes and food to be most important for the benthic fauna in the adjacent Skagerrak. Recruitment of larvae of many benthic species on deep bottoms is strongly dependent of the supply from the south going current from the Skagerrak. Biotic factors are more difficult to study but predation is most likely of great importance for the benthic fauna (Moksnes et al., 2008).

Changes in the fauna in the Kattegat have been reported that could be related to eutrophication. Pearson et al. (1985) reported signs of eutrophication in comparing benthic fauna with Petersen's results from the early 1900s. Rosenberg et al., 1995pointed to hypoxia, salinity and temperature as structuring factors for benthic communities in the especially eutrophicated Laholm Bay in the southeast Kattegat.

1.6. Factors influencing area of distribution of the benthic fauna besides temperature

The nutrient development along the entire Swedish coastline shows declining trends between 1975 and 2005 (Andersson and Andersson, 2006) and therefore an impact of eutrophication on the benthic fauna is likely reduced in later years. Concentrations of heavy metals and traditional organic xenobiotics are also generally being reduced in fauna and sediments, yet there are some concerns regarding new substances (Bignert et al., 2011) including micro plastics (Andrady, 2011). Bottom trawling fishery on Norway lobster *Nephrops norvegicus* is intensive and occurs more or less daily on the silty-clay bottoms deeper than 30 m in the central Kattegat. In this study the three deepest stations N10, N12 and N14 are probably impacted by this activity. Even if it is unknown how the benthic communities would have appeared without the trawl disturbance, species sensitive to physical disturbance showed higher abundance in areas with low trawl activity compared to areas with higher activity (Pommer et al., 2016).

The American invasive polychaete *Marenzelleria viridis* has been found since 2006, but only in low abundances at shallow bottoms (Göransson and Olsson, 2015). The ctenophore *Mnemiopsis leidyi*, originally native to the western Atlantic-coastal waters, was first recorded in 2006 at the Swedish west coast. This species could have significant impact on the ecosystem by preying on zooplankton (Purcell et al., 2001). It is also a powerful predator on pelagic benthos larvae (Ivanov et al., 2000).

1.7. Temperature and climate change

The temperature in the Kattegat has increased significantly both in the surface water (about 2 °C) and bottom water (about 1.5 °C) during the period between 1971 and 2009. This increase was largest in the 2000s (Palmbo and Andersson, 2010). Temperature increased also at all monitored stations in this study in the Kattegat between 1993 and 2013 (Hultcrantz and Skjevik, 2014). Potentially this might have a long term impact on the species composition. Primarily it could be expected that species with the southernmost area of distribution will increase or immigrate whilst the equivalent northern species diminish or disappear when water temperature increases (Hiscock et al., 2004; Birchenough et al., 2015). An increase in the water temperature also reduces its ability to dissolve oxygen which might elevate the frequency and duration of oxygen depletion in the bottom water (Altieri and Gedan, 2014). However, primary production might also decrease at an increase in temperature (Henriksen, 2009). Ocean acidification can also be related to climate change (Kroeker et al., 2013) but impacts are yet unknown in the studied area.

The sensitivity of the fauna in the studied area probably varies depending on the species composition. Temperature is especially

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