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Distribution of benthic macrofaunal communities in the western Baltic Sea with regard to near-bottom environmental parameters. 1. Causal analysis

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ABSTRACT

In this study we relate patterns in the spatial distribution of macrofaunal communities to patterns in near-bottom environmental parameters, analysing the data observed in a limited area in the western Baltic Sea. The data used represents 208 stations, sampled during the years 2000 to 2007 simultaneously for benthic macrofauna, associated sediment and near-bottom environmental characteristics, in a depth range from 7.5 to 30 m. Only one degree of longitude wide, the study area is geographically bounded by the eastern part of the Mecklenburg Bight and the southwestern Darss Sill Area. Spatial distribution of benthic macrofauna is related to near-bottom environmental patterns by means of various statistical methods (e.g. rank correlation, hierarchical clustering, nMDS, BIO-ENV, CCA). Thus, key environmental descriptors were disclosed. Within the area of investigation, these were: water depth, regarded as a proxy for other environmental factors, and total organic content. Distinct benthic assemblages are defined and discriminated by particular species (*Hydrobia ulvae–Scoloplos armiger*, *Lagis koreni–Mysella bidentata* and *Capitella capitata–Halicryptus spinulosus*). Each assemblage is related to different spatial subarea and characterised by a certain variability of environmental factors. This study represents a basis for the predictive modeling of species distribution in the selected study area.

1. Introduction

The relative roles of the environment, competition, predation and chance in determining the composition of communities have been largely debated in animal ecology (Austin, 1987). Some main factors usually named as responsible for benthos distribution are: food supply, water salinity, oxygen concentrations, current energy, temperature, turbidity, substrate composition, sedimentation rates and bathymetry (e.g. Wildish, 1977; Wilson, 1991; Bromley, 1996; Olenin, 1997; Laine, 2003; Coleman et al., 2007). It is important that a heuristic approach is taken for both validation and iterative development of ecological models across a range of spatial scales. An exploratory statistical description of the prevailing ecological structure of the observations made on site is always the indispensible first step (Bourget and Fortin, 1995); it should also be supported by an improving mechanistic understanding (Thrush et al., 2003).

The following study can be referred to a comparatively fine spatial scale. Depending on the scale, different processes determine the spatial structure; therefore, inferences derived for one spatial scale cannot be extrapolated to another scale (Legendre and Legendre, 1998). Our results comprise a detailed analysis of benthic community composition regarding near-bottom habitat characteristics of the area stretching through the Kadetrinne incision from the eastern Mecklenburg Bight to the southwestern Darss Sill area. The aim of the present investigation was to analyse the causal relations between benthic macrofauna and selected environment variables: water depth, near-bottom salinity and oxygen concentrations, total organic content, median grain size, as well as sorting, skewness, and permeability. An appropriate technique for predictive modeling of species distribution regarding the available abiotic data was defined and applied in Gogina et al. (2009-this volume). Additionally, the modeling results for selected species were mapped. Hence, the present work describes a causal analysis — a basis and a necessary first step towards the design of models able to predict species distribution.

2. Materials and methods

2.1. Study area

Depending on the scale and region, salinity together with near-bottom oxygen concentration is often regarded among the major factors affecting the species richness and composition of macrozoobenthic communities (e.g. Olenin, 1997; Zettler et al., 2000; Laine, 2003). By defining the study area, we aimed to lessen the dominance of these two factors in the analysis to illuminate the impact of others. The study area is attached to the region of Mecklenburg Bight (Fig. 1) close to the very beginning of the Baltic salinity gradient and that is

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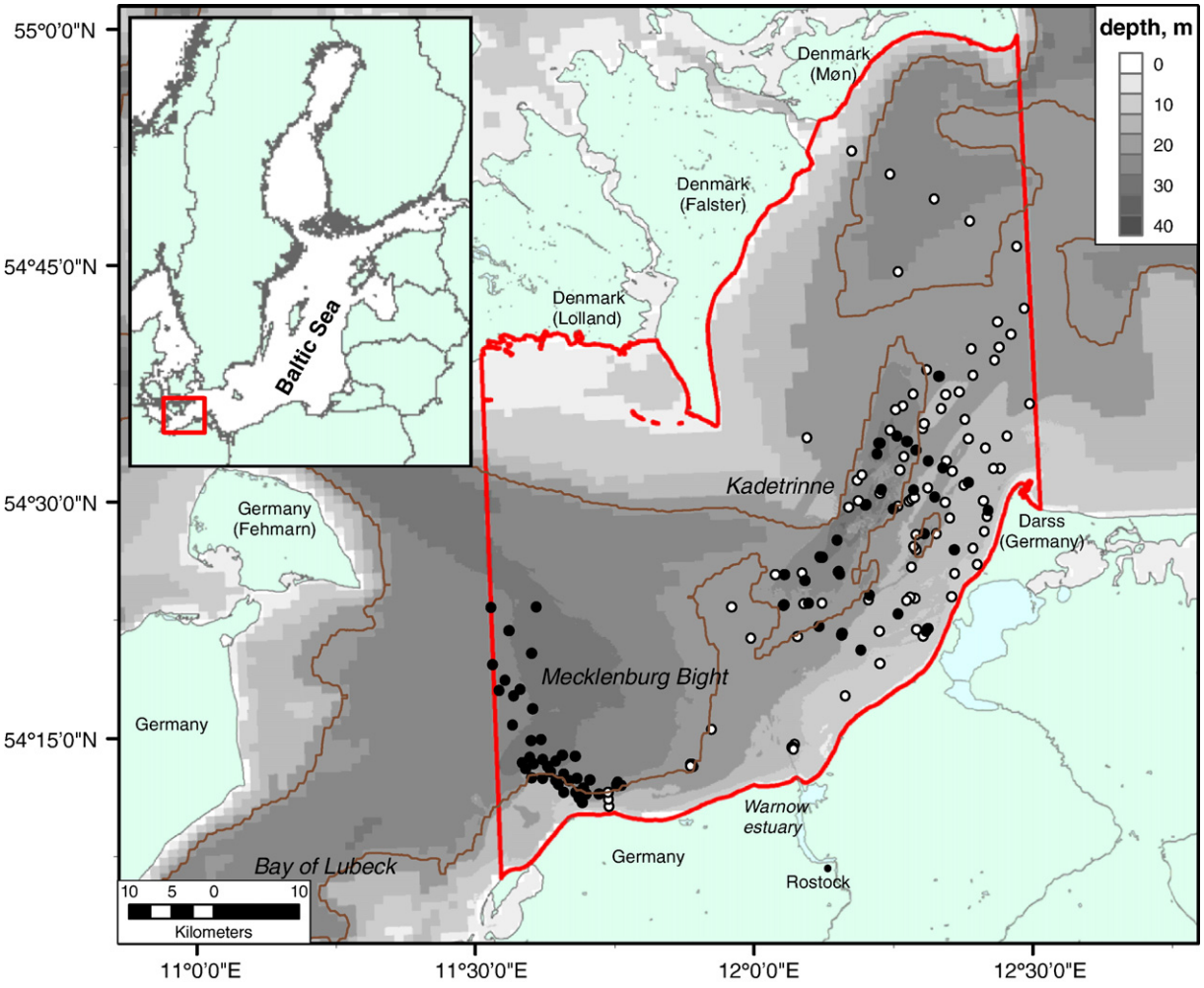

Fig. 1. Investigation area is bordered by the thick line, distribution of 208 sampling stations is presented; dots are stations covered with quantitative (abundance of benthic species) data; filled dots indicate 72 stations with a full set of data available for all eight abiotic variables. Thin line is the 18 m isobath which separates the two depth subareas of our region. Geographical data ESRI (1998); projection UTM on WGS84. The colour version of this figure is available online. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

why it is richer in macrofaunal species (with significant presence of both marine and brackish water species at the same time) than the inner, less saline, parts of the Baltic Sea.

The study area is assigned to the transition zone between the North Sea and the Baltic Sea. Barotropic and baroclinic gradients and local winds force currents that are controlled here by the bathymetry and stratification. Positive water balance caused by freshwater supply results in the outflow of brackish Baltic Sea water at the sea surface. Sea level differences forced by large scale winds drive the inflow of high saline Kattegat water into the transition zone. Density differences, mainly due to salinity, dominate the farther transport into the central parts of the Baltic. Local winds and thereby generated waves are important for vertical mixing in shallow waters. Particularly in summer, the thermal stratification stabilizes the water column and supports the salinity stratification, with halocline and thermocline occurring in the central part of the investigation area at around 12–16 m (Siegel et al., 2009). Generally, near-bottom salinity declines in the eastwards direction, dropping down in areas near the coastline due to the freshwater river runoff or the isolation from currents. Depending on the scale and region, salinity together with near-bottom oxygen concentration is often regarded among the major factors affecting the species richness and composition of macrozoobenthic communities. To lessen the dominance of those two factors and illuminate the effects of others we restricted the area to reduce the variability of both factors in distinct depth-zones, whereas other factors are represented in wide ranges. Whereas the range of near-bottom salinity in the whole area is relatively high (99.5% of sampling points lie within a salinity range of 8.3–21.8 PSU), the variability in distinct depth-zones is lower (i.e. salinity varied from 9 to 16 PSU at approximately 75% of stations shallower than 18 m; and ranged from 15 to 22 PSU at the same percentage of stations below 18 m). The hypoxic events, connected with absence of oxygen-rich saline water inflows and formation of steady hydrographical stratification in the water column, run differently in various locations of the region and irregularly take place in the late summer–autumn period, e.g. in deepest parts of Mecklenburg Bight. However, they are not as frequent and their effect is not as dramatic (at least within the investigation time) and long-lasting as it is known for the deep basins of the Baltic Proper.

The study site ranges in the northwards direction approximately from 45 to 75 km and about 63 km in the eastwards direction. Within these boundaries the area amounts to about 4000 km^2. With an average depth of 16 m (depth at sampling points ranges from 7.5 to 29.9 m) its water volume approximates 46 km^3 (data origin: this study). The sea floor is characterised mainly by postglacial sand and gravel deposits, with organic-rich silt-size sediments observed in the deepest parts of Mecklenburg Bight (Bobertz and Harff, 2004).