Climate-related long-term trends and spatial variability in the zooplankton community of the Central Baltic Sea

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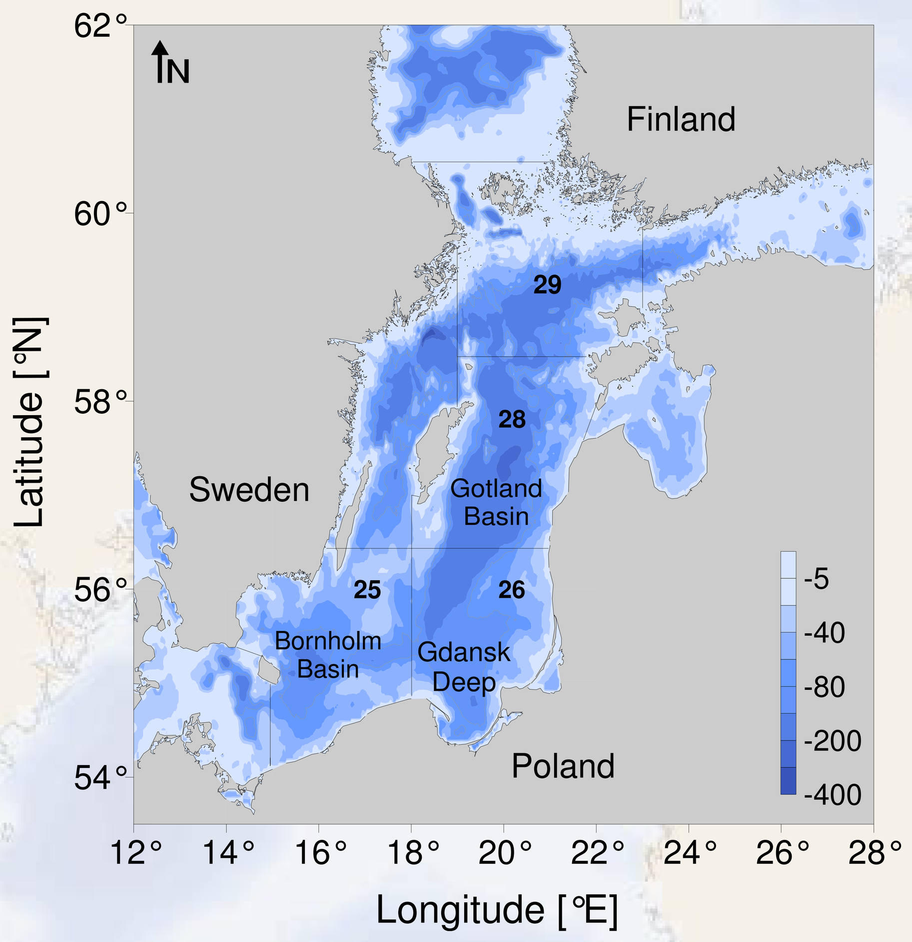
Background

In recent decades the Baltic Sea underwent drastic climate- and fisheries-related changes in pelagic ecosystem structure and functioning. Specifically an ecosystem regime shift affecting all trophic levels was observed during a period from the end of the 1980s to early 1990s. Zooplankton is the major link between upper and lower trophic levels. Their components usually display fast reaction on changes in their physical environment, being thus a reliable indicator of climate effects on marine ecosystems. Here, we present first results of a re-analysis of zooplankton long-term dynamics in different areas of the Baltic Sea (ICES subdivisions SD 25, 26, 28, 29). We extracted temporal trends and identified regime-like changes. Synchronicity or differences in the observed zooplankton dynamics between areas were investigated and potential driving forces identified.



Data

Time series of 7 major zooplankton taxa, covering at max. the period from 1960 to 2008, were used to investigate spring (May) interannual and spatial variability. Data sets were derived by LATFRA[2] and IOW[3].

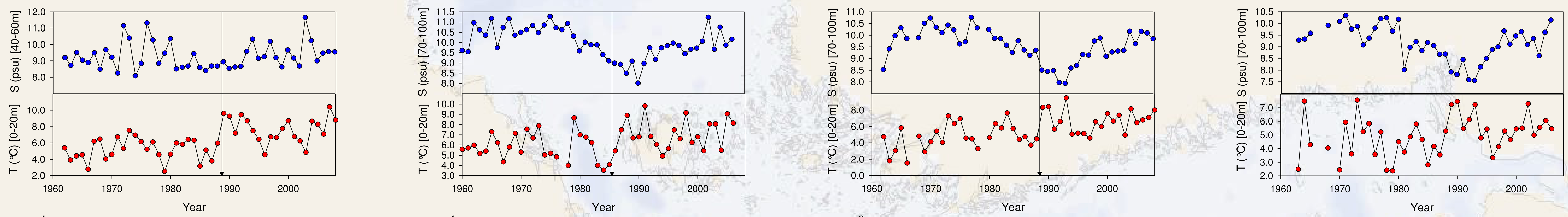
Data treatment:

1. Species abundances (N/m³) were averaged between samples per SD and year, and based on this a multi-annual overall mean was calculated.
2. For SD 25 a single time series was generated using both data from LATFRA and IOW: for years, where both datasets overlapped, weighted annual means were calculated from log10(x+1) transformed annual mean abundances of each time series and back-transformed to original abundances.
3. To account for gear specific capture efficiencies and different spatial and temporal resolutions, log10(x+1) transformed anomalies were used in the analysis (Mackas & Beaugrand, 2010)

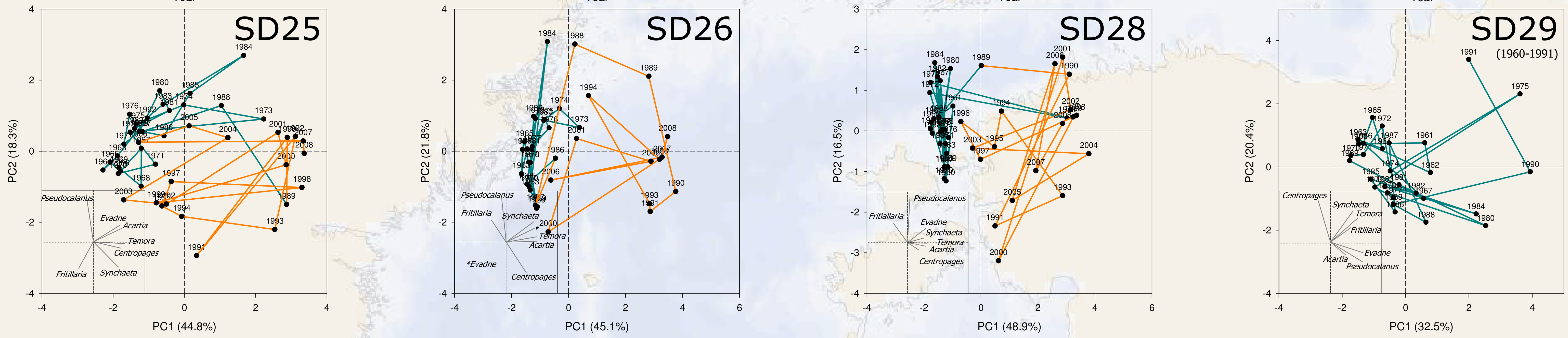
Area-specific interannual dynamics

Average spring salinity in the upper halocline in each of the four SDs

Average near-surface temperature in each of the four SDs *(Arrows indicate timing of shifts in zooplankton data)*



Standardised Principal Component Analysis (PCA) of Chord Distance transformed data per SD (Legendre & Gallagher, 2001): Time-trajectories of PC1 vs. PC2; colours represent time periods identified by Chronological Clustering on the α-level 0.01 (Legendre et al., 1985).
Small graphs illustrate species loadings on the first factorial plane.



Relation to abiotic drivers

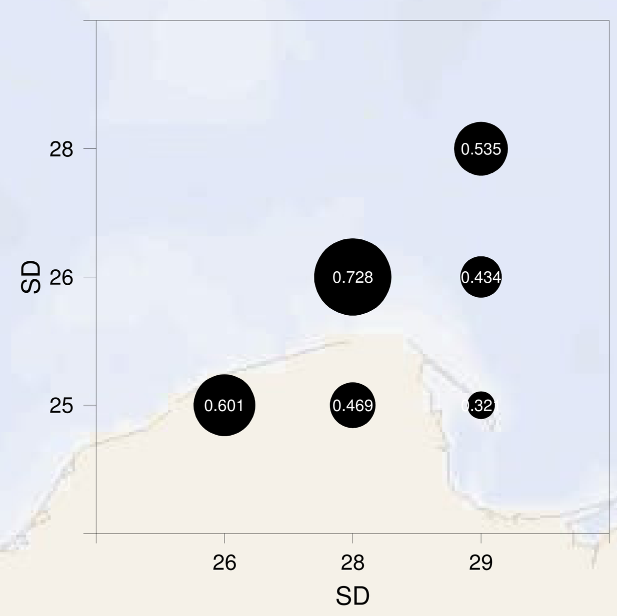
Generalised Additive Models (GAMs) (Hastie & Tibshirani, 1990) to analyse the importance of hydrographic and atmospheric parameters on zooplankton species assemblages in spring: The table represent the most parsimonious models, relating the zooplankton state index (PC1 of the respective PCA) to environmental variables (spring temperature & salinity, North Atlantic Oscillation (NAO), Atlantic Multidecadal Oscillation (AMO)). Model selections are based on GCV and adjusted r^2.

SD	Predictors	GCV	r^2 (%)
25	Temperature***, AMO*	1.1654	78.6
26	Temperature***, Sa linity*, NAO**	0.8911	90.5
28	Temperature***, AMO***	1.4111	73.5

p-level for variables:
* = 0.05; ** = 0.01; *** = 0.001

Correlation between areas

Results of a Mantel test based on Spearman correlation coefficient to analyse the temporal agreement between area-specific zooplankton Chord-Distance Matrices:
Size of the circles represent the Spearman rank correlation coefficient (all significant). Highest correlation is observed between SD 26 and SD28 with r_S=0.728



Key findings

Hydrographic conditions varied similarly over time, especially in SD 26, 28 and 29, with biggest year-to-year variations in the mid- to late 1980s. Accordingly, zooplankton communities showed significant shifts in 1988-1989 (SD25 and 28) and in 1985-1986 (SD26). Because the time series in SD29 ended in 1991, no significant change point could be identified.

Time-trajectories showed that year-to-year variability in all zooplankton time series is high, especially in the latter period since 1990. Significant correlations were observed between area-specific zooplankton dynamics, with strongest relationships between neighbouring areas. Preliminary GAM analyses revealed upper water temperature (0-20m) to be the main driver for differences in the zooplankton community in all areas. Salinity was only significant in SD 26, whereas in all areas the atmospheric parameters AMO or NAO played a role.

References:
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Mackas, D.I. and Beaugrand, G. (2010). Comparisons of zooplankton time series. *J. Mar. Sys.* 79: 286-304.

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