Time-series analysis of winter zooplankton in the English Channel: biodiversity, size diversity and trophic interaction

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Summary
Biodiversity is a key aspect of the good environmental status (GES) of an ecosystem. Higher diversity is assumed to be related to a higher stability of the system. As size is an indicator for trophic position, correlates with physiological traits and as species generally differ in size, size diversity may also be a suitable statistic for GES, but can be sampled faster, cheaper and automatically with optical devices in contrast to time-consuming taxonomic classification. Here we present a unique time-series from 1988 to 2014 on winter zooplankton size, abundance and taxonomic composition sampled on the International Herring Larvae Survey station grid in the Eastern English Channel. We analysed zooplankton using a semi-automatic system, i.e. ZooScan, and followed patterns in taxonomic- and size diversity over time. Our results suggest that the combination of size diversity and normalized biomass size spectrum (NBSS) are suitable indicators for regime shifts and changes in zooplankton dynamics. They may further serve as indicators for the zooplanktonic prey biomass available to fish and their larvae. In conclusion, even though taxonomic diversity is crucial to describe GES, size diversity and NBSS can serve as additional descriptors for ecosystem functioning and may be integrated into an GES approach.

Introduction
Regime shift analyses have taught us that abundance does not serve alone as an indicator of a healthy stock status. It is rather the distribution (e.g. south to north) or availability (e.g. pelagic to demersal) of biomass within an ecosystem that may shift and lead to different, yet stable regimes (Beaugrand 2004). Since then biodiversity has become a major research parameter used to define good environmental status. However, size diversity on the other hand has so far been neglected despite faster and simpler optical measuring possibilities. Complementing the few permanent zooplankton observatories in the North Sea and the limited studies covering winter conditions we present a "new" long-term dataset based on the International Herring Larvae Survey in the Downs region during January, which in addition includes size diversity. Here, changes in the size spectra over years may result in reflect or cause regime shifts and/or decreased larval survival of important commercial fish species that may go undetected if only biodiversity is considered.

Materials and Methods
Samples were taken during the annual International Herring Larvae Survey from 1988 to 2014 using a modified Gulf III plankton sampler with a mesh size of 300 μm and stored in formaldehyde. The survey takes place in the Downs region, ICES area IVc and VIId every January. As fish larvae and eggs are regularly counted to be included in the Herring assessment they were not included in the samples and have thus not been considered here. Samples were scanned using a ZooScan and size (equivalent spherical diameter: ESD) was determined with ImageJ software for each individual. Due to technical limitations (optical resolution) zooplankton was grouped by major orders like "copepoda". Shannon-Wiener diversity indices were then calculated for both biodiversity and size diversity. Furthermore we applied cluster and regime shift analyses (Rodionov, 2004) to detect possible changes in the ecosystem based on abundance and size.

Results and Discussion

Zooplankton in the Downs region underwent dynamic changes over the past decades. Both size and biodiversity show a correlated, deceasing trend (R^2=0.58; p<0.001). The size diversity time series can be separated into three episodes: high diversity until 1996, a dynamically changing diversity during the late 1990s and early 2000s and comparatively low diversity since 2010 (Fig.1). These trends are also visible in the biodiversity and were confirmed by regime shift analysis (not significant for 1997 shift concerning biodiversity). Considering the time-consuming work of taxonomic identification and the detailed expert knowledge in plankton taxonomy, size diversity may act as a suitable, cheap and objective indicator for biodiversity.

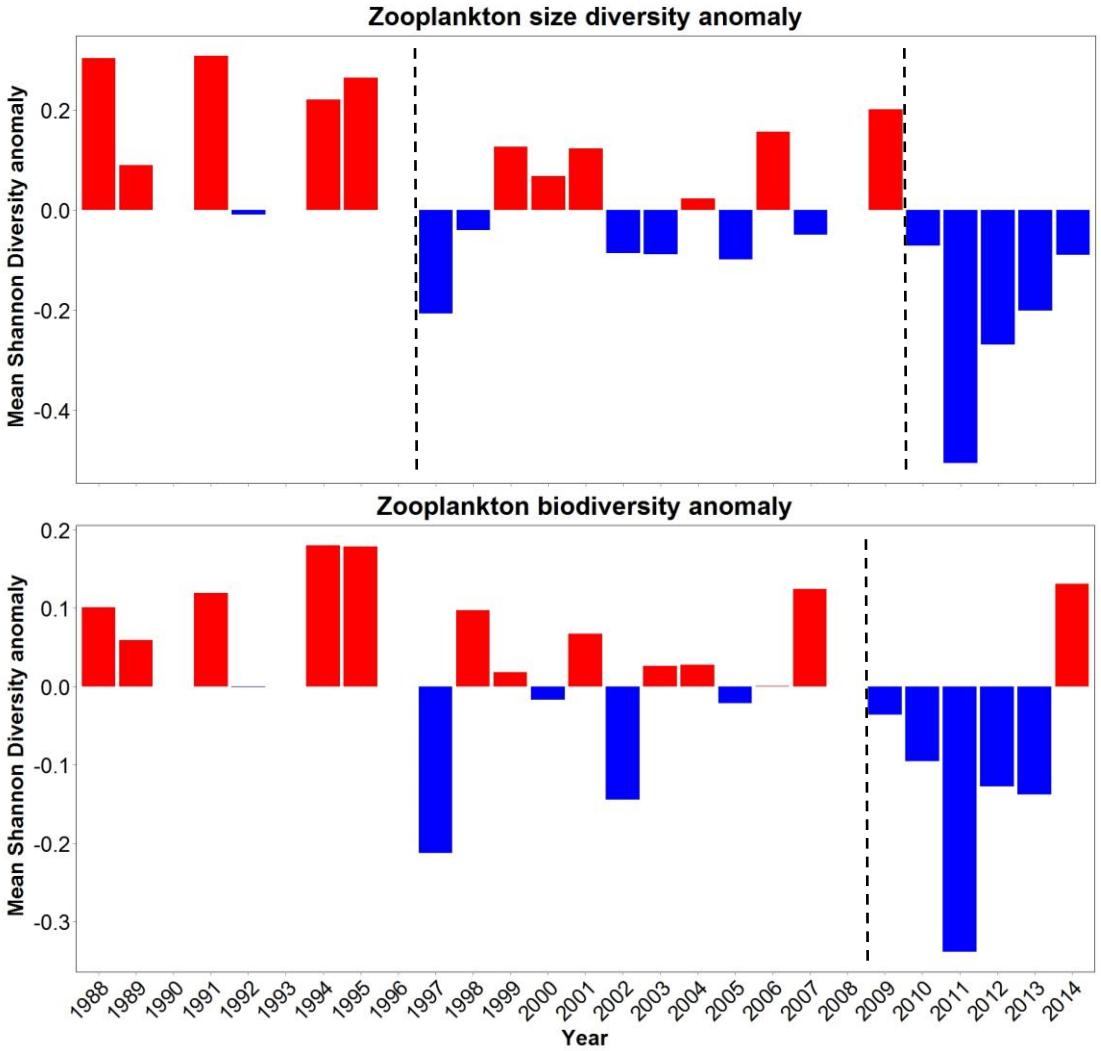

Figure 1: Anomalies of Shannon-Wiener size and biodiversity index from the mean across all years. Dashed line show years of significant regime shifts.

Considering the poor recruitment of autumn spawning herring it is still questioned as to what extent the larval survival is bottom-up or top-down controlled. Our analysis suggests that due to the change in size of zooplankton as potential prey during the years of recruitment failure zooplankton grew out of the predator pit. Hence, the good environmental status may have changed accordingly.

References

Beaugrand, G. 2004. The North Sea regime shift: evidence, causes, mechanisms and consequences. Progress in Oceanography, 60: 245-262.

Rodionov, S.N. 2004. A sequential algorithm for testing climate regime shifts. Geophysical Research Letters 31: L09204