Environmental filtering drives functional diversity of fish assemblages in a temperate system

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Summary
Presence and survival of species in a community depend on their capacities to maximize fitness in a given environment. The study of processes that control survival and co-existence, termed assembly rules, follows various mechanisms, primarily related to biotic or abiotic factors. To determine assembly rules ecological similarities of co-occurring species are often investigated. This can be evaluated using functional biodiversity indices summarizing the traits and niches of species in a given community. In order to investigate the underlying processes shaping community assembly in marine ecosystems, we investigate the patterns and drivers of fish community composition in the Baltic Sea. Our results show a marked spatial decline in species- and functional richness, largely explained by decreasing salinities. Furthermore, we show that the fish community is functionally more similar than expected by random chance alone. This implies that environmental filtering, acting along the salinity gradient, is the dominant factor shaping community composition. However, community composition in the eastern part, an area beyond the steep decline in salinity, was characterised by fewer species with largely different traits characteristics, hence community assembly in the east follows a neutral process. Our results provide knowledge on key abiotic drivers impacting marine fish communities and their functional vulnerability to environmental changes.

Introduction
The processes that control survival and co-existence of species in a community, termed "assembly rules", are a focal point of community ecology (Keddy, 1992). The Baltic Sea is characterized by a pronounced environmental gradient illustrated by marked changes in temperature, salinity and oxygen conditions from the Kattegat to the northern Baltic proper. This environmental gradient is known to influence species distribution, as only a few marine species are able to reproduce and survive in the cold brackish conditions. Hence, the Baltic Sea is a species poor ecosystem (Bonsdorff, 2006) with a pronounced decrease in richness along the environmental gradient, as shown for benthic macrofauna (Törnroos *et al.*, 2015). Due to the pronounced environmental gradients, the Baltic Sea serves as an ideal marine case study to investigate the underlying processes shaping community assembly and patterns of species richness and functional diversity.

Materials and Methods
The demersal fish dataset used in this study is extracted from the Baltic International Trawl Survey Database for the period 2003-2014 (DATRAS: www.datras.ices.dk). We derived the presence, absence and mean catch-per-unit-effort (CPUE) of species per haul and per ICES square. Traits on diet, habitat and reproduction were collected for the 42 demersal species that were occurring regularly (present at least every 2 years). Species richness and functional richness indices were calculated and mapped per ICES square. The observed relationship between FRic and SR was compared with a null model, constructed from random drawn of species, to disentangle the underlying assembly rules with the hypothesis that observed values inside the 50% confidence intervals correspond to neutral assembly, whereas observed values under the 25% or above the 75% correspond to environmental filtering or limiting similarity assembly rules, respectively. The distribution of species abundance in each haul

was also taken into account by calculating a weighed dissimilarity index (wFDiss) based on the traits dissimilarity of each pair of species. The results were analyzed according to environmental variables.

Results and Discussion

SR was characterized by a pronounced decrease from the Kattegat (>30 species) to the northern Baltic proper (<10 species). This spatial pattern was driven by the abiotic environment, especially by the pronounced salinity gradient. Habitat dominance and oxygen also showed significant negative and positive relationships, respectively and together with salinity explained 92.5% of the variability. FRic followed a similar decreasing pattern as SR but remained high until the Bornholm basin (15-16°E) despite a pronounced decrease in SR. Salinity was the best explanatory variable explaining 53.8% of the variability, habitat dominance was also significant.

FRic and SR showed a saturating relationship where after a certain level of SR (~15-20 species), an increase in SR did not increase FRic further. For low SR (<15 species), the observed FRic was not significantly different than expected from the null model, while for high SR (>23 species) FRic became significantly smaller (Fig. 1). The communities with high SR but low FRic were primarily found in the western part of the area (Kattegat and Skagerrak), while east of 14°E (Baltic proper), most communities were not significantly different from the null model. The wFDiss index had a similar spatial structure: communities with low wFDiss, i.e. functionally similar abundant species, were mainly present in the western part, while communities with wFDiss close to a neutral value and therefore with species neither functionally similar nor dissimilar, were mainly located east of 14°E. Few hauls, all located in the eastern part of the area, had a high wFDiss (>0.55), i.e. with abundant species functionally different.

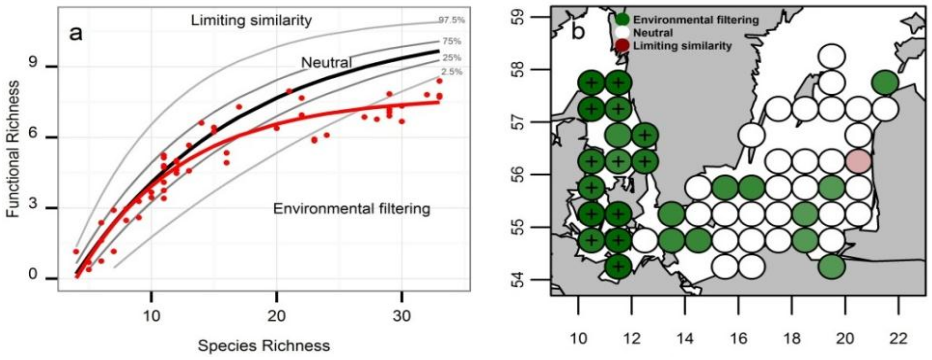

Figure 1. (a) Observed (red dots) and simulated FRic values based on a random null model (bold black line). 50% and 95% confidence intervals are represented in grey lines. (b) Map of the differences between observed and simulated FRic

We showed that the functional richness in the Baltic Sea is lower than expected from a null model, hence only a slight decrease could have severe consequences on the health and functioning of the ecosystem. Being bordered by nine countries, the Baltic Sea is a complex socio-ecological system, which is undergoing high anthropogenic pressures. Therefore, in an already highly impacted ecosystem, understanding the processes that structures community composition and its main abiotic drives is of key concern for ecosystem management efforts striving to maintain a healthy and productive system now and in the future.

References

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