The pressure is on! How different human activities affect functional diversity in soft-bottom macrobenthos.

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There is an increasing awareness that knowledge of the functional diversity of a community is key to understand how the community responds to environmental and anthropogenic stressors. It is also expected that indicators derived from biological traits could be more suitable to quantify the sensitivity of benthic communities. These functional indicators can then be used to detect changes in ecosystem functioning within environmental impact assessment programs. The Belgian Part of The North Sea (BPNS) represents a highly dynamic area that is subject to a variety of human activities. Within this study, the impact of three different activities - dredge disposal, sand extraction and offshore wind energy – was evaluated by assessing differences in functional diversity.

A total of ten relevant traits were selected, subdivided in 44 modalities, incorporating both response- and effect traits. Effect traits are those which affect ecosystem properties while response traits explain a species' response to disturbances in the environment (Bolam *et al.*, 2016). Functional diversity was then quantified by calculating different indices: functional richness, functional divergence, functional evenness, functional dispersion and Rao's quadratic entropy. Shifts in trait composition due to anthropogenic pressure were determined by Fuzzy Correspondence analysis (FCA). These FCA biplots were produced for each case and location, focusing on the response and effect traits separately. By comparing the pairwise distances of the impact categories within the FCA plot, the trait modalities that drive or explain the shift in communities were identified.

The analyses were performed on data from 2006-2016 at the dredge disposal sites, linked to three macrobenthos habitat types (*Abra alba*-, *Limecola balthica*- and *Nepthys cirrosa*-habitat; Breine *et al.* 2018), data from 2009-2016 at three main sand extraction areas and data from 2017-2018 at two offshore wind farms (C-Power and Belwind). Dredge disposal and sand extraction stations were divided into four impact categories ranging from 'none' to 'high', while the windfarm stations were allocated to either 'impact' or 'control' according to their distance from the turbines.

Apart from FDiv, all of the indices showed a response to the different impact levels and type of disturbance. FRic between the highest impact level and control was significantly lower in two of the habitats for the dredge disposal case, but nearly significantly higher for the heaviest impacted sand extraction area. FDis and RaoQ followed the same trend and were highest at high levels of dumping but lower at the highest level of sand extraction. FEve had a varied (decrease/increase) response according to case and impact category. Within the offshore wind farms, findings for the functional diversity indices were less pronounced and only FRic was significantly elevated at impact sites of C-Power at Thorntonbank. Nevertheless, impact and control stations of both windfarms were fairly well separated in the FCA biplots and had the same five trait-modalities associated with the impact stations: small maximum body size, short lifespan, active brood care, exoskeleton and no larval stage. This visual separation on one of the two FCA ordination axes was less pronounced for the sand extraction and dredge disposal cases, indicating minor shifts in trait-modality composition.

The different types of impacts and levels of disturbance provided the ideal platform to assess the potential of biological trait-based indicators. While responses appear to be complex and case-dependent, results from this study show that the implementation of this type of analysis should be considered as a complementary tool in future environmental impact assessments.

Keywords: Functional diversity indices; Biological trait analysis; Fuzzy correspondence analysis; Macrobenthos; BPNS; Dredge disposal; Offshore windfarms; Sand extraction