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Can benthic quality assessment be impaired by uncertain species sensitivities?

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ABSTRACT

This study tested robustness of mathematically defined species sensitivity with manipulation of disturbance gradient coverage by datasets on two different pressures and two depth zones of the central Baltic Sea. The results indicate large differences of sensitivity values for the same species when depth range changed. After addition of samples from impacted sites to the control datasets, estimated sensitivity values decreased for half of analysed species. Sensitivity of tolerant species appeared to be highly dependent on the coverage of disturbance gradient by the dataset, while sensitive species were highly robust to this effect. Although pressure type and coverage of disturbance gradient by the dataset was important, sensitivity changes were primarily linked to the altered environmental conditions. It is suggested that sensitivity values based on natural variability of pre-selected communities will better integrate the role of important environmental factors and increase robustness of discrimination between disturbed and undisturbed sites.

1. Introduction

Healthy marine environments with diverse biological communities and good environmental status provide valuable ecosystem services and support a wide range of human activities (Elliott, 2011). Marine ecosystems are, however, exposed to an increasing number of disturbances such as eutrophication, over-fishing, pollution, etc. (Lotze et al., 2006). In the face of these multiple pressures, an accurate assessment of environmental status is a prerequisite for establishing environmental targets and selecting specific management measure.

Stationary and long-living benthic communities can amalgamate medium-to-long term information about environmental conditions and the importance of anthropogenic pressures, therefore structural parameters of bottom macrofauna communities were synthesized in a number of multimetric indices to be used for environmental status assessment (Borja et al., 2013). Following guidance for recent assessments of environmental status, these indices integrate sensitivity, richness and abundance of macrofauna species (Water Framework Directive; 2000/60/EC; Marine Strategy Framework Directive; 2008/56/EC; HELCOM, 2013). While richness and abundance are directly assessed from benthic samples, defining species sensitivity is less straightforward.

Generally, sensitivity is described as a product of a likelihood of damage due to pressure (termed intolerance or resistance) and the rate of, or time taken for recovery once the pressure has been removed (termed recoverability or resilience) (Laffoley et al., 2000; OSPAR, 2008). Typically, very sensitive species react fast to the impact of natural stressors or human activity (e.g. low resistance) and recover only after a prolonged period, if at all (e.g. low recoverability).

Species grouping into sensitivity classes based on expert valuation is used in several indices (e.g. AMBI, Borja et al., 2000; BENTIX; Simboura and Zenetos, 2002; M-AMBI, Muxika et al., 2007, Leonardsson et al., 2009). Typically this approach enables one to take into account different sensitivity meanings (e.g. resilience, resistance, recoverability and vulnerability) (Tyler-Walters et al., 2001), which otherwise are difficult to quantify using numerical algorithms. Additionally, expert-based sensitivity values may have a fixed range of variability, predefined number of sensitivity classes and fixed distance between sensitivity values for organisms belonging to different sensitivity classes. These features make species sensitivity estimates well-structured and simple to interpret in a context of overall status assessment.

In contrast to expert opinion, standardized mathematical algorithm for assessing species sensitivity has an obvious advantage for screening sensitivity performance under different conditions. It also makes sensitivity values comparable between different areas and datasets leaving less freedom for low certainty assumptions. So far, the only standardized species sensitivity assessment algorithm was proposed by Rosenberg et al. (2004) and recently revised by Leonardsson et al. (2015). The overall concept relies on the assumption that lower sensitivity species will be more abundant and will occur more frequently in disturbed sites, characterized by lower species richness, while species of higher sensitivity will attain higher abundance at higher species richness and less disturbed sites. This implies that sensitivity value is dependent on the diversity (i.e. disturbance) range covered by the dataset and may significantly influence the overall assessment. However, since its invention the only studies of exploring variability and reliability of

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estimated sensitivity values were recently carried out by Leonardsson et al. (2015) and Schiele et al. (2016). The authors of the first study found that species sensitivity estimates vary depending on proportion of samples from disturbed and undisturbed areas, and there is no universal ratio between these two groups of samples for maximum precision of sensitivity values for all species. The second study (Schiele et al., 2016) demonstrated that sensitivity of taxa varied between Baltic regions and the ratio between high and low sensitivity species was decreasing from polyhaline areas to mesohaline and oligohaline waters.

In this study we aim at further reliability testing of sensitivity estimates with manipulation of disturbance gradient coverage by datasets on two different pressures (dumping and benthic trawling) and two depth zones. We raise two major questions for this study: i) whether species sensitivity values depend on disturbance type, and ii) if yes, how large this impact can be in a context of sensitivity variation along the local environmental gradients. We use two datasets from neighboring areas of the central Baltic and quantify an extent of species sensitivities and BQI change after addition of disturbed sites into assessment.

2. Material and methods

2.1. Study area

The study was carried out in the Lithuanian waters of the south-eastern part of the Baltic Sea, at depths ranging from 40 m to 65 m (Fig. 1). Although average surface salinity remains relatively constant over time, halocline at the 60–80 m depth range separates shallow bottoms with fairly stable salinity of 7–8 psu from deeper bottom layer with salinities varying around 11–12 psu (Olenin et al., 1996). Within and below the halocline local patches, azoic sediments are temporary observed due to anoxic conditions (Olenin, 1997). Fields of medium sand (median grain size between 0.25 and 0.5 mm) typically occur down to a 40 m depth and are followed by fine sands (median grain size between 0.125 and 0.25 mm) down to 50–60 m. At the deeper areas, muddy sediments are the most widespread, although patches of coarse aleurites are reported down to 70–90 m depth.

In total 16 soft bottom macrozoobenthos species were recorded in the monitoring data in the study area at depths from 30 to 70 m (Marine Research Department, 2015). Crustaceans, polychaetes and bivalves were the most diverse taxonomic groups comprising 37%, 26% and 16% of the total recorded taxa respectively. Bivalve *Macoma balthica* and spionid polychaetes *Marenzelleria* spp. and *Pygospio elegans* typically dominate the biomass at depths down to 50–60 m (Bubinas and Vaitonis, 2003; Olenin and Daunys, 2004). In deeper areas, other taxa (e.g. Ostracoda, *Bylgides sarsi*, *Monoporeia affinis* etc.) become dominant in low diversity benthic communities with low macrofauna density.

Study sites were distributed in the areas of two types of impacts: dredge spoil dumping and benthic trawling (Fig. 1). Dredged spoil dumping area (17.8 km^2) is located at depths of 40–50 m approx. 20 km from the coastline, south-west of the mouth of the Curonian lagoon. Approx. 10 mln m^3 of dredged material, mainly moraine mixed with clay (70%) was deposited in the area from 2000 to 2010. Due to its relatively remote location, the dumping area is rarely affected by reduced salinity of the Curonian lagoon plume (Vaičiūtė et al., 2012). Enhanced concentrations of Cd, Cu, Pb have been recorded in the dumping site during environmental monitoring (e.g. Marine Research Department, 2015). Also, local dumping effects on macrofauna communities, particularly reflected in decrease of *P. elegans* abundance, have been reported earlier (Olenin, 1992).

The extent of the bottom trawling in the Lithuanian exclusive economic zone was currently investigated by analysing the VMS data for the recent decade (Daunys et al., in prep.). Bottom trawling occurs in approx. 2/3 of the total EEZ area with the annual average intensity (i.e. relative coverage of the area by trawling activity) of 13.7 $\pm$ 0.7% for 1×1 nm grid. This study was performed in the most intensively trawled areas located in the south-western part of the EEZ at depths of 60–65 m, where the annual trawling intensity was typically higher than 50% and exceeded 200% in some years.

2.2. Benthic macrofauna sampling and data analysis

Macrofauna species sensitivity analysis was based on two datasets (166 benthic samples from 60 stations in total), each representing a different dominant pressure in spatially restricted zones (Fig. 1): i) dredge spoil dumping area at depths between 40 and 50 m; ii) five areas with benthic trawling activity within the halocline zone at depths of 60–

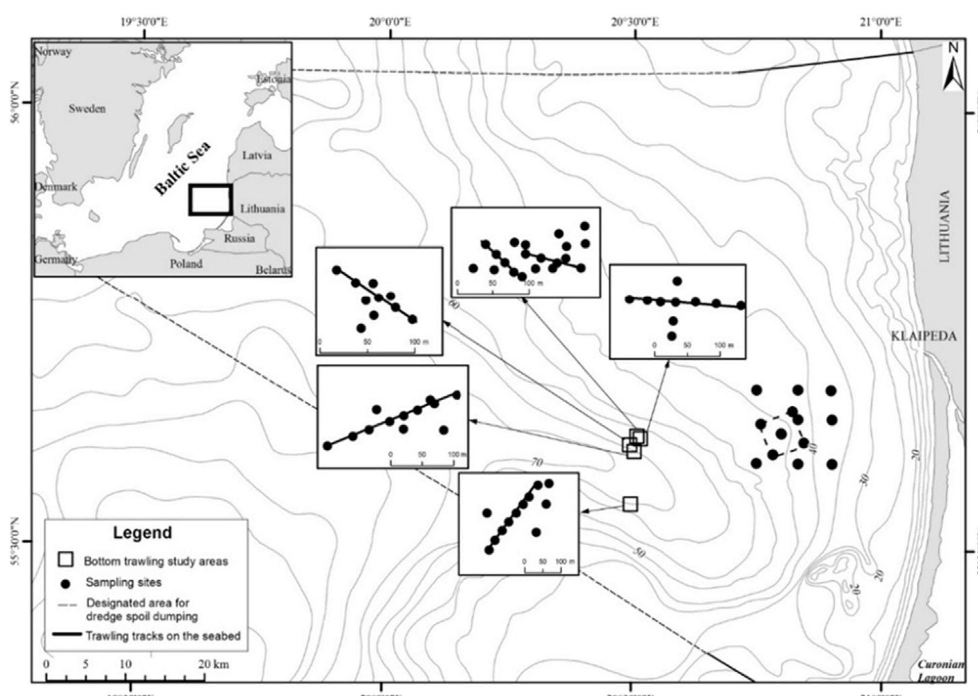

Fig. 1. Distribution of sampling sites within the study area in the south-eastern part of the Baltic Sea.

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