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Long term changes in the status of coastal fish in the Baltic Sea

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Management for sustainable coastal ecosystems is benefited by coherent large scale status assessments to support the identification of measures, but these efforts may be challenged by both data availability and natural biogeographical variation. Coastal fish are a resource for commercial and recreational fisheries as well as significant contributors to coastal ecosystem functioning, by linking lower and higher levels of the food web. This study addresses long term changes in coastal fish communities at Baltic Sea regional scale, in order to identify overall trends and support the operationalization of large scale status assessments of marine biota. The study was focused on two indicators representing the functional groups of *Piscivores*, which are attributed to changes in food web processes including predation/fisheries, and *Cyprinids*, which are associated with eutrophication. The indicators were assessed for trends within ten-year intervals, using data combined from national monitoring programs during 1991–2013. The results showed predominantly declining trends in *Piscivores* and of increases in *Cyprinids* during the studied three decades, both indicative of a deteriorating status. The pattern was however reversed in the most recent years. Similar results among adjacent areas were identified in some cases, but overall differences at local scale were high, indicating strong influence of local processes. The results suggest that coordinated local measures in order to abate cumulative effects are a preferred way of improving the overall status of coastal fish. The latest studied time intervals were the overall most stable and could be considered as potential baseline years for upcoming regional assessments.

1. Introduction

The contribution of coastal areas to human livelihood and ecosystem function is highly rated globally (de Groot et al., 2012). With respect to fish communities, coastal areas provide important habitats for spawning, recruitment and foraging for many species, and are thereby an important basis for commercial, household and recreational fisheries (Rönnbäck et al., 2007; Seitz et al., 2014). Coastal fish are also an important link between lower and higher levels of the food web, as a food source for fish, birds and mammals, and contributing to ecosystem functionality by top down regulation (Boström et al., 2012; Eriksson et al., 2011, 2009; Östman et al., 2013; Sieben et al., 2011).

A prerequisite for providing these functions is obviously that the long-term viability of coastal fish species and size structures is ensured (UN, 1992). Various anthropogenic pressures, such as habitat degradation, overfishing, eutrophication and pollution threaten the environmental status of coastal areas and coastal fish communities (Airoldi and Beck, 2007; Lotze et al., 2006). In order to improve the situation, large scale status assessments and management approaches are increasingly requested. For the Baltic Sea region in northern Europe, the Baltic Sea Action Plan (BSAP; HELCOM, 2007) was launched in order to initiate coordinated actions towards a healthy marine environment. Shortly thereafter, the Marine Strategy Framework Directive (EC, 2008) was initiated, whereby member states of the European Union assigned to achieving good environmental status in the marine environment

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according to commonly agreed definitions (EC, 2010). Such initiatives depend on coherent assessment strategies to support the evaluation of progress. However, one typical challenge is a lack of comparable data, due to biological reasons or differences in monitoring methods (Argillier et al., 2013). This is also true for coastal fish species with no or low commercial importance, which are monitored and managed nationally or locally. In the Baltic Sea region, a regionally coordinated international network was established in order to share expertise and perform common assessments of coastal fish data (Ådjers et al., 2006; HELCOM, 2006, 2012). However, due to differences in national implementation, several differences in how coastal fish monitoring is implemented occur (HELCOM, 2015).

Another challenge is that many coastal species may respond to environmental changes acting at several geographical scales, making it potentially difficult to identify appropriate management actions. For coastal fish, various studies have shown evidence of local changes in response to local environmental conditions (Fabricius et al., 2005; Guidetti et al., 2002; Hansson, 1987; Mustamäki et al., 2014; Repečka, 2005; Snickars et al., 2015; Sundblad et al., 2014). This is an expected response in coastal resident fish species that typically have short migration distances and local population structure (Elliott and Dewailly, 1995; Laikre et al., 2005a, 2005b; Olsson et al., 2012b; Olsson et al., 2011; Saulamo and Neuman, 2002). On the other hand, coastal fish may also be affected by environmental factors acting in concert at larger geographical scale, caused by changes in climate or anthropogenic pressures (Eriksson et al., 2011; Last et al., 2011; Olsson et al., 2012a), or local effects occurring simultaneously in many areas may be important for overall status at larger scale (Mustamäki et al., 2014; Sundblad and Bergström, 2014).

The aim of the present study was to meet these challenges by applying an indicator-based approach for combining and assessing monitoring data from mixed sources in the same setup. In order to support a coherent evaluation of status in relation to common environmental objectives (HELCOM, 2007; EC, 2008) a set of common regional indicators were recently developed for several organism groups (HELCOM, 2013a). The indicators used in the present study represent two dominating functional groups of coastal fish: *Piscivores* (predators) and *Cyprinids* (predominating mid-trophic level group). The indicators were selected in order to be independent of species identity, to ensure comparability across geographical areas despite potential natural differences in species composition. For the *Piscivore* indicator, high values were expected to signal a healthier environmental state. The indicator is positively associated with the availability of fish for human consumption and food web functionality due to the role of piscivores in regulating food web process (e.g. Rönnbäck et al., 2007; Sieben et al., 2011). For the *Cyprinid* indicator, high values were expected to signal a more deteriorated state, as this indicator is associated with eutrophication and nutrient enriched areas (Ådjers et al., 2006; Snickars et al., 2015; both indicators are further described below). However, for none of the indicators, baseline values for setting quantiative boundaries for good environmental status have yet been identified, and their overall spatial patterns and historical trends have not been assessed.

The objectives of the study were to elucidate the predominating long term trends in Baltic Sea fish communities according to the two indicators, in order to support their further development. The following questions were asked: 1) Have increasing or decreasing trends in each indicator predominated over time; 2) During what time periods were the changes most frequent; and 3) In what geographical areas were the changes most frequent? By this, the results also give a unique overview of the predominating status of Baltic Sea coastal fish communities from year 2000 onwards.

2. Methods

2.1. Study area

The Baltic Sea is among the largest brackish water seas on Earth, with salinity from 10 to 12 at its entrance down to nearly zero in its inner parts. The sea is shallow, with an average depth of ca 60 m, and 15–20% of the area less than 10 m deep (Nordic Council of Ministers, 1996). The coastline is varied in terms of habitat types. Long exposed sandy shores occur mainly in the south and southeast, and complex archipelagoes mainly in the northern parts (Al-Hamdani and Reker, 2007). The Baltic Sea is essentially non-tidal, with relatively stable salinity conditions locally. Due to the brackish conditions, species of a marine and freshwater origin coexist. The number of marine species gradually diminishes towards the inner parts, and species of freshwater origin become more dominating (Ojaveer et al., 2010). In addition, freshwater species are common near-shore in all areas (Hällfors et al., 1981).

Data was obtained from ongoing coastal fish monitoring in Estonia, Finland, Latvia, Lithuania and Sweden (Fig. 1). Additionally, data from the Finnish commercial coastal fisheries was used in order to increase sampling density and fill gaps in geographical coverage. Data from the years 1991–2013 were included, although some monitoring series were initiated earlier. All data series covered a minimum of ten consecutive years within this time frame, in total 32 data sets (Table 1).

The studied monitoring areas were mainly semi-sheltered areas close to the coastline or in the archipelago. These were identified in order to, as far as possible, not be subject to direct anthropogenic impact. However, some variation was inevitable in relation to local nutrient loading from rivers and freshwater outflows. Also, effects of fishing may be expected, as this is not prohibited in any of the areas. Due to natural topographical differences, there was also variation among areas in for example level of water exchange and proximity to important recruitment areas, which may affect their natural capacity for supporting coastal fish populations (Sundblad et al., 2014).

2.2. Monitoring methods

Sampling was performed using bottom set gillnets, as described in further detail by HELCOM (2015). Monitoring initiated before the 2000s (1991–2013) was performed using Net Series, except in the Gulf of Bothnia where Coastal Survey Nets were used. Monitoring initiated during the 2000s was performed using Nordic Coastal Multimesh Gillnets (2002–2013).

The Net Series consist of nets with different mesh sizes which are linked to each other (mesh sizes 17, 21.5, 25 and 30 mm bar length; in DAU and JUR also 33 and 38 mm). Each gear was 1.8 m deep and 120–180 m long. The Coastal Survey Nets are two linked multimesh nets composed of five panels with different mesh sizes (17, 21, 25, 33 and 50 mm). Each gear is 3 m deep and 70 m long. For both gear types, sampling was performed between 2 and 5 m depth at 2–6 stations, and was typically repeated 3–6 nights in a row (see HELCOM, 2015 for further details). The Nordic Coastal Multimesh Gillnets were composed of nine panels with different mesh sizes (10, 12, 15, 19, 24, 30, 38, 48 and 60 mm). Each gear is 1.8 m deep and 45 m long. Sampling was performed at 30–45 stations distributed over four depth strata (0–3, 3–6, 6–10 and 10–20 m). Only samples from 0 to 10 m depth were included here, corresponding to 30–40 stations per area. One net was set at each station, and each station was fished one night.

The nets were set late in the day and lifted the next morning. Catch per unit effort (CPUE) was calculated as the number of fish per net and fishing night, separately for each species. The Net Series