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Can guild- or site-specific contrasts in trends or phenology explain the changed role of the Dutch Wadden Sea for fish?

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ABSTRACT

The Wadden Sea bordering the Dutch, German and Danish coast, is traditionally a region with important functions for many fish species: as a nursery area for juveniles (marine juveniles), as a feeding area, as a transit to and from fresh water, and resident species complete their whole life cycle there. Because of indications that the importance of the Dutch Wadden Sea has changed drastically for many species during the past decades, we analysed and classified trends of 24 common fish species in the last 45 years, which were assigned to 5 different ecological guilds. Trends were examined for three Wadden Sea regions and compared to trends in the adjacent two North Sea coastal regions. For these analyses we made a combined use of two longterm time series: an annual beamtrawl survey, the Demeral Fish Survey (DFS) with a high spatial but poor seasonal resolution and a fyke series with a high seasonal but poor spatial resolution. We investigated for which species the DFS survey was appropriate for trend analysis, and we evaluated whether a change in timing may contribute to patterns in DFS time trends.

Total fish biomass showed a similar pattern in all tidal basins with an increase from 1970 to 1980, a peak in the mid-1980s and a strong decline from 1980 to 2000, with a subsequent stable trend. The pattern in the coastal region deviated especially in the past 10 years, with a further decline along the Dutch Wadden coast and an increase along the mainland coast. Most dramatic declines throughout the Wadden Sea occurred in species belonging to the marine juvenile guild, notably plaice, sole and dab. A declining trend in marine juveniles is on-going in the western part, while it recently stabilised or even increased in the central and eastern part and in the coastal regions. Resident species showed more variable trends in the Wadden Sea with less pronounced directions: both increases and decreases occurred. In the coastal regions, several resident species have increased considerably in the last 15 years, a pattern not observed in the Wadden Sea. Also the size structure of the fish community changed in all regions, with generally the strongest declines in the largest size classes. The combined use of the two surveys showed that for some species the DFS was not timed in the period of peak occurrence. Although the phenology of several species has changed, the DFS survey period still encompasses the peak period of most species.

1. Introduction

Many fish species rely on shallow coastal habitats for at least one of their life stages. A suite of flatfish, other groundfish and pelagic fish species reach these regions as postlarvae and spend their juvenile phase here (marine juveniles) (Elliott et al., 2007; van der Veer et al., 2000). Other species inhabit the region on route to either marine or fresh water spawning sites (diadromous species) or during certain times of the year (marine seasonal migrants) or only occasionally (marine adventitious species) (Elliott et al., 2007). In addition to temporary visitors, many species spend (almost) their entire life in shallow waters (estuarine residents) (Elliott and Hemingway, 2002). Naturally such coastal regions support large numbers of fish (Elliott and Hemingway, 2002) that make use of the suitable habitat characterised by a high food availability.

The Wadden Sea is a coastal region for which its function for various fish species has been described (Couperus et al., 2016; Tulp et al., 2008; van der Veer et al., 2015; van der Veer et al., 2001; Zijlstra, 1972). The region connects fresh water habitat with the North Sea and provides a variety of habitats consisting of intertidal mudflats, gullies ranging in depth from several decimetres to 30 m. The borders consist of salt

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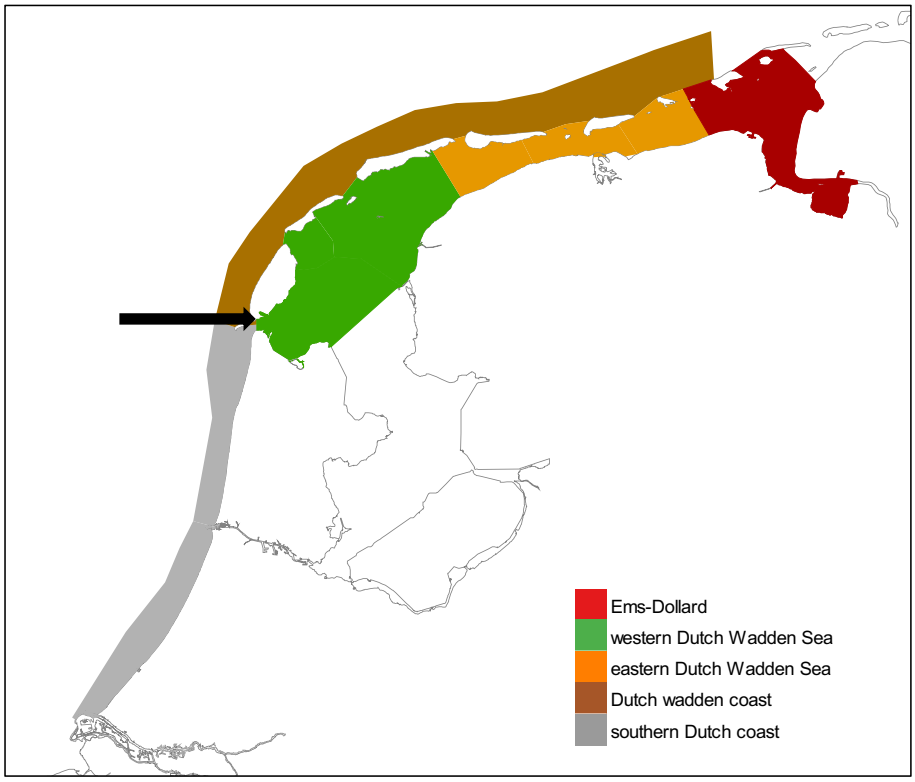

Fig. 1. Map of the study area showing the five regions used in the analyses. The arrow indicates the location of the NIOZ fyke.

marshes, which are cross-cut by gullies. Both intertidal and subtidal habitats have been shown to be of great importance to both commercial and non-commercial species. Structural monitoring of the fish fauna has taken place since 1960/1970 by two major monitoring programs: a fyke program in the western Wadden Sea (the NIOZ-fyke, run by the Royal Netherlands Institute for Sea Research, NIOZ) and an annual beam trawl survey (the Demersal Fish Survey, DFS, run by the Institute for Marine Resource Studies, IMARES) covering the entire Dutch Wadden Sea as well as the Dutch coastal region.

The NIOZ-fyke programme running since 1960 has shown that many species are declining in the western Wadden Sea and that especially large sized fish have disappeared lately (van der Veer et al., 2015; van der Veer et al., 2011). Trends in the Dutch Wadden Sea as a whole based on the DFS, and covering the period from 1970 have been previously analysed (Tulp et al., 2008). At different levels throughout the ecosystem contrasting trends were found between tidal basins within the Wadden Sea (Ens et al., 2009; Marencic and de Vlas, 2009; Tulp et al., 2012). These tidal basins greatly differ in sediment type, nutrient levels, salinity, water visibility and stoichiometry (Wolff, 1983). Because a basin approach in time-series analysis may provide better insight in potential drivers, the DFS data were reanalysed per region (consisting of two or three tidal basins) separately. Adjoining coastal regions north of the islands and along the mainland Dutch coast are included in the comparative analysis as well, to provide a reference for the patterns observed within the Wadden Sea. By structuring the fish species according to the specific guilds and analysing guild-specific developments, species spending their entire life in the Wadden Sea and those that spend only part of their life there can be distinguished, which could help identifying whether the cause for declining trends must be sought inside or outside the Wadden Sea.

In the course of the 40 years of survey, the timing of the DFS in the Wadden Sea advanced approximately one month because of practical planning reasons, which might partly explain trends in fish species: if the residence period of fish in the Wadden Sea has changed, such phenological changes in combination with a change in timing of the survey may lead to time trends that do not reflect true population changes. The NIOZ fyke scheme provides day to day values for fish abundance and was used here to test if the DFS was timed in the right period for different species.

Table 1
List of fish species (in systematic order) analysed with scientific and common names, and information on guilds. Guild: ca = diadromous; er = estuarine resident; mj = marine juvenile; ms = marine seasonal; ma = marine adventitious. [1]Sandeel consists of at least two species: *Ammodytes tobianus* and *Ammodytes marinus*, belonging to different guilds. Because *A. tobianus* is likely to be the most numerous in the study area, we classified the sandeel species group here under estuarine resident species.

Common name	Scientific name	Guild
Eel	*Anguilla anguilla*	ca
Herring	*Clupea harengus*	mj
Sprat	*Sprattus sprattus*	ms
Smelt	*Osmerus eperlanus*	ca
Whiting	*Merlangus merlangus*	mj
Cod	*Gadus morhua*	mj
Bib	*Trisopterus luscus*	mj
Five-bearded rockling	*Ciliata mustela*	er
Pipefish sp.	*Syngnathus* sp.	er
Tub gurnard	*Chelidonichthys lucerna*	mj
Bullrout	*Myoxocephalus scorpius*	er
Hooknose	*Agonus cataphractus*	er
Common seasnail	*Liparis liparis*	er
Eelpout	*Zoarces viviparus*	er
Rock gunnel	*Pholius gunnellus*	er
Sandeel sp.[1]	*Ammodytes* sp.	er
Greater sandeel	*Hyperoplus lanceolatus*	mj
Common dragonet	*Callionymus lyra*	ma
Gobies sp.	*Pomatoschistus* sp.	er
Brill	*Scophthalmus rhombus*	mj
Flounder	*Platichthys flesus*	er
Plaice	*Pleuronectes platessa*	mj
Dab	*Limanda limanda*	mj
Sole	*Solea vulgaris*	mj