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Changes over 50 years in fish fauna of a temperate coastal sea: Degradation of trophic structure and nursery function

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ABSTRACT

The ongoing daily sampling programme of the fish fauna in the Dutch Wadden Sea using fixed gear was analysed for the years 1960–2011. Spring sampling caught immigrating fish from the coastal zone and autumn samples reflected emigration of young-of-the-year. In total 82 fish species were caught with no clear trend in biodiversity. In both spring and autumn total daily catch fluctuated and peaked in the late 1970s. From 1980 to the present catches of both pelagic and demersal species showed a 10-fold decrease in total biomass. Mean individual biomass decreased in spring between 1980 and the present from about 150 to 20 g wet weight. No trend was found in autumn mean individual biomass which fluctuated around 20 g wet weight. The trophic structure remained constant for both the demersal and bentho-pelagic fish fauna from 1980 to 2011, whilst the trophic position of pelagic fish in spring fell from about 3.9 to 3.1. Min/max auto-correlation factor analysis showed similar trends in spring and autumn species biomass time series: the first axis represented a decrease from the 1960s followed by stabilization from the mid-1990s. The second trend showed an increase with a maximum around 1980 followed by a steady decrease in spring and a decrease and stabilization from 2000 in autumn. It is argued that the most likely explanatory variables are a combination of external factors: increased water temperature, habitat destruction in the coastal zone (sand dredging and beach nourishment, fishing) and increased predation by top predators for the first trend, and large-scale hydrodynamic circulation for the second trend. We conclude that both the trophic structure of the coastal zone fauna and the nursery function of the Wadden Sea have been reduced since the 1980s. Our findings corroborate that ecological change in coastal ecosystems has not only occurred in the past but still continues.

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1. Introduction

Coastal ecosystems have been under pervasive human disturbance for centuries (Jackson et al., 2001) with historical evidence worldwide for major structural and functional change due to overfishing. The current challenges relate not only to overfishing, but the combined effects of it with climate change (e.g., warming, acidification, deoxygenation), habitat destruction and pollution (Bijma et al., 2013; European Marine Board, 2013).

Present findings on long-term changes in fish communities are primarily based upon information from commercial catches, landings and stock assessments. Most ecological research addressing full communities is of shorter duration and cannot give a long historical perspective. Furthermore, most observations are from the open sea while cumulative impacts of human behaviour are considered most severe in shallow coastal waters. To examine long-term changes in coastal fish communities and identify their possible causes, we analyse a 50 year consistent time series of fish fauna in the Dutch part of the international Wadden Sea, the largest coastal ecosystem bordering the North Sea.

The Wadden Sea is a typical example of a coastal ecosystem under long-term anthropogenic pressure. Key changes in the Dutch part include the decline of the harbour seal (Reijnders and Lankester, 1990); disappearance of the bottlenose dolphin (Reijnders and Wolff, 1983); loss of the commercial spring herring fishery; pollution events (Essink and Wolff, 1983); embankments;

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eutrophication (De Jonge et al., 1996; Philippart et al., 2007) and species introductions (Wolff, 1992; Van Walraven et al., 2013).

Daily monitoring of the fish fauna using fyke nets in the western part of the Dutch Wadden Sea started in 1960 and has continued without change in methodology ever since (Van der Meer et al., 1995). The main advantage of this passive sampling device is that it samples both pelagic and benthic components of mobile fauna. It has been demonstrated that fyke catches are representative of a much larger area and that they represent an, on-average, constant sampling fraction of the fauna for all the abundant and most of the rare species (Van der Meer et al., 1995). Non-commercial fyke catches such as these supply the best available data of changes in the marine ecosystem as sampling methods have not been influenced by economics, management, fishing technology and targeting patterns as normally occurs (Branch et al., 2010).

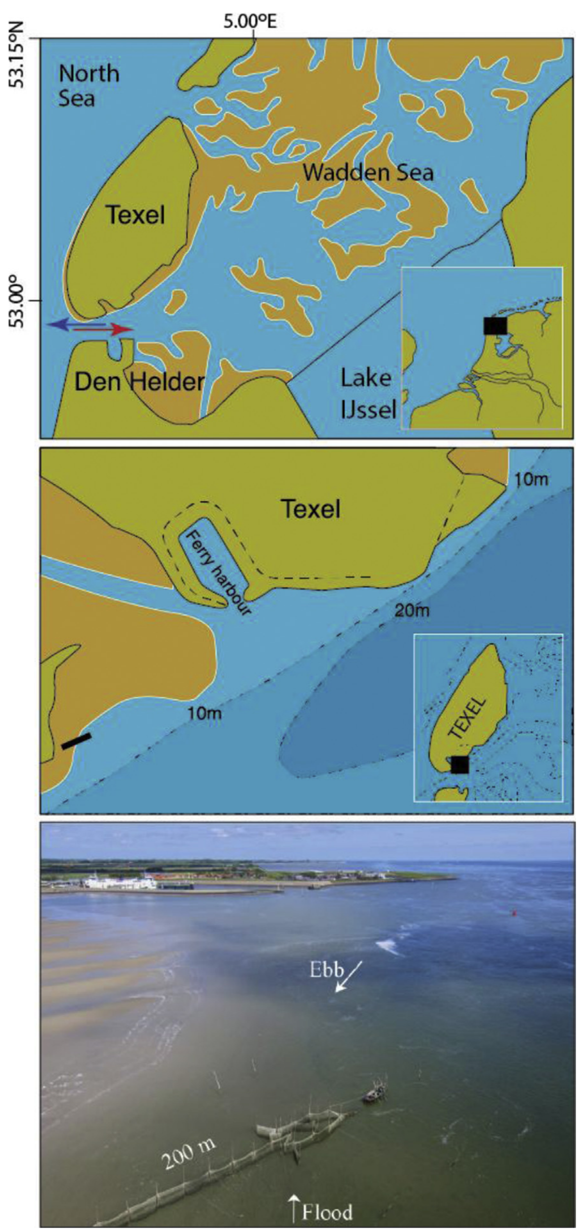

Fig. 1. The sampling location near the island of Texel. Upper panel: western Dutch Wadden Sea; red arrow indicates inwards migration in spring and blue arrow outward migration in autumn. Middle panel: fyke net position (black bar); Orange: intertidal areas. Lower panel: Arial photograph taken from a southwestern angle (courtesy of Lodewijk van Walraven).

Previous papers on these fyke catches dealt with fish recruitment (Philippart et al., 1996), long-term variability in the abundance of the brown shrimp *Crangon crangon* (Campos et al., 2010), bass *Dicentrarchus labrax* (Cardoso et al., 2015) and gelatinous zooplankton (Van Walraven et al., 2015). In this paper, long-term trends in the coastal fish community are analysed by addressing the following questions: [1] what are the long-term patterns in the fish community; [2] are these long-term trends associated with environmental factors, and [3] is there an impact of climate change visible?

2. Material and methods

2.1. Sampling

A passive fish trap near the entrance of the Dutch Wadden Sea (Fig. 1) was used. This 'kom-fyke' (Nédélec, 1982) has a leader of 200 m running from above the high water mark into the subtidal where two chambers collect the fish and other specimens. The stretched mesh-size of the leader and the chambers was 20 mm. In the area, the semidiurnal lunar tide is dominating and tidal range varies between 1 and 2 m depending on weather conditions and lunar phase. Tidal currents normally do not exceed 1 m s^{-1}, except for periods with strong wind stress. Fishing started in 1960 and has continued ever since where the kom-fyke was emptied every morning irrespective of tidal phase, except when prevented by bad weather. In most years, the kom-fyke was removed just before winter because of potential damage by ice floes and in summer because of fouling of the net and potential clogging by macroalgae and jellyfish.

Catches were sorted immediately, and all individuals were identified up to species level. For each species, numbers were counted and sometimes, when numbers were large, only wet mass was determined. Prior to data analysis, wet masses were transformed into counts, using a fixed ratio per month, i.e. a fixed mean individual mass based on the actual measurements from 1970 onwards. All information was stored in a database.

A suite of environmental parameters was collected which were considered to potentially influence fish communities (Table 1). Large-scale hydrodynamic circulation was indexed by the North Atlantic Oscillation (NAO) during winter (Dec–March). Fish performance during winter (Dec–Feb) and summer (July–Aug) was indexed by water temperature, salinity and visibility (Secchi disk readings), obtained from long-term monitoring programmes at the NIOZ sampling jetty, located < 1 km east of the kom-fyke. Primary productivity was indexed by mean summer values (May–Sept) of concentrations of chlorophyll-*a* (μg l^{-1}), total-N and total-P (mg l^{-1}; sum of dissolved inorganic, dissolved organic, and particulate compounds) in the Marsdiep basin. As nutrient concentrations only covered part of the sampling period, loadings of total-N and total-P discharged from Lake IJssel (the main freshwater source of the Marsdiep) were also included. Habitat destruction was captured by the amount of sand dredging, the amount of beach nourishment and the intensity of shrimp fisheries in the coastal zone of the North Sea and cockle fisheries in the intertidal of the Wadden Sea. To index predation pressure by top predators, abundance estimates of cormorants in the western Wadden Sea, and numbers of harbour and grey seals in the Dutch Wadden Sea and coastal zone were multiplied by their respective daily food requirements [cormorants: 575 g wet mass d^{-1} (Leopold et al., 1998); harbour seal: 2.5 kg wet mass d^{-1}, grey seal: 3 kg wet mass d^{-1} (IMARES, Brasseur pers. comm.)] and summed.

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