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Journal of Sea Research 60 (2008) 54–73

JOURNAL OF SEA RESEARCH

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Signals from the shallows: In search of common patterns in long-term trends in Dutch estuarine and coastal fish

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Received 7 March 2008; received in revised form 29 April 2008; accepted 29 April 2008
Available online 10 May 2008

Abstract

Shallow waters along the North Sea coast provide nursery areas for juveniles of commercially exploited species and natural habitat for resident species and seasonal visitors. The areas have gone through major changes in the last decades due to climate change and human activities such as fishing and eutrophication and changes in abundance of apex predators. Using a long-term dataset we present trends from 1970 to 2006 in 34 fish species in three coastal areas in the Netherlands: the Dutch Wadden Sea, the Westerschelde and the Dutch coastal zone. The patterns varied widely among individual species as well as between the three areas. Total fish biomass showed a dome shape pattern with an increase from 1970 to 1985 and a subsequent decline until the early 2000s. Based on multivariate and time series analyses we explore possible correlations of fish density with a predefined set of three categories of environmental variables: abiotic, biotic and fisheries related variables. Dynamic factor analysis (DFA) identified one common trend for every area: for the Wadden Sea and Westerschelde increasing from the 1970s to the early 1980s followed by a steep decrease until the mid 1990s, a temporary period (until 2002) of increase for the Wadden Sea, and a continuing increase for the Westerschelde. The common trend in the Dutch coastal zone shows a similar increase but a time lag compared to the estuarine areas, while the distinct decline was absent here. The species that showed the strongest correlation with this common trend differed between the areas, and explains the difference between the common trend in the coastal zone with that in the estuarine areas. Common trends were best described by models containing variables from all categories of environmental variables (only maximum 2 tested at a time).

Keywords: Fish; Biomass; Wadden Sea; Dutch coast; Westerschelde; Time series analyses; Dynamic factor analysis

1. Introduction

Shallow coastal areas in the Netherlands such as the Wadden Sea and Westerschelde have long been regarded important nursery areas for the juveniles of many North Sea fishes (Zijlstra, 1976; Bergman et al., 1989; van Beek et al., 1989). Nurseries are areas where juveniles aggregate and where survival and growth are enhanced through better feeding conditions, refuge opportunities and high connectivity with other habitats. After they have reached a certain size or age, they leave the nursery area and recruit to the (sub)adult populations (Pihl et al., 2002). Other species visit these shallow areas only seasonally. In addition to marine juveniles and seasonal migrants there are also several resident species

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doi:10.1016/j.seares.2008.04.004

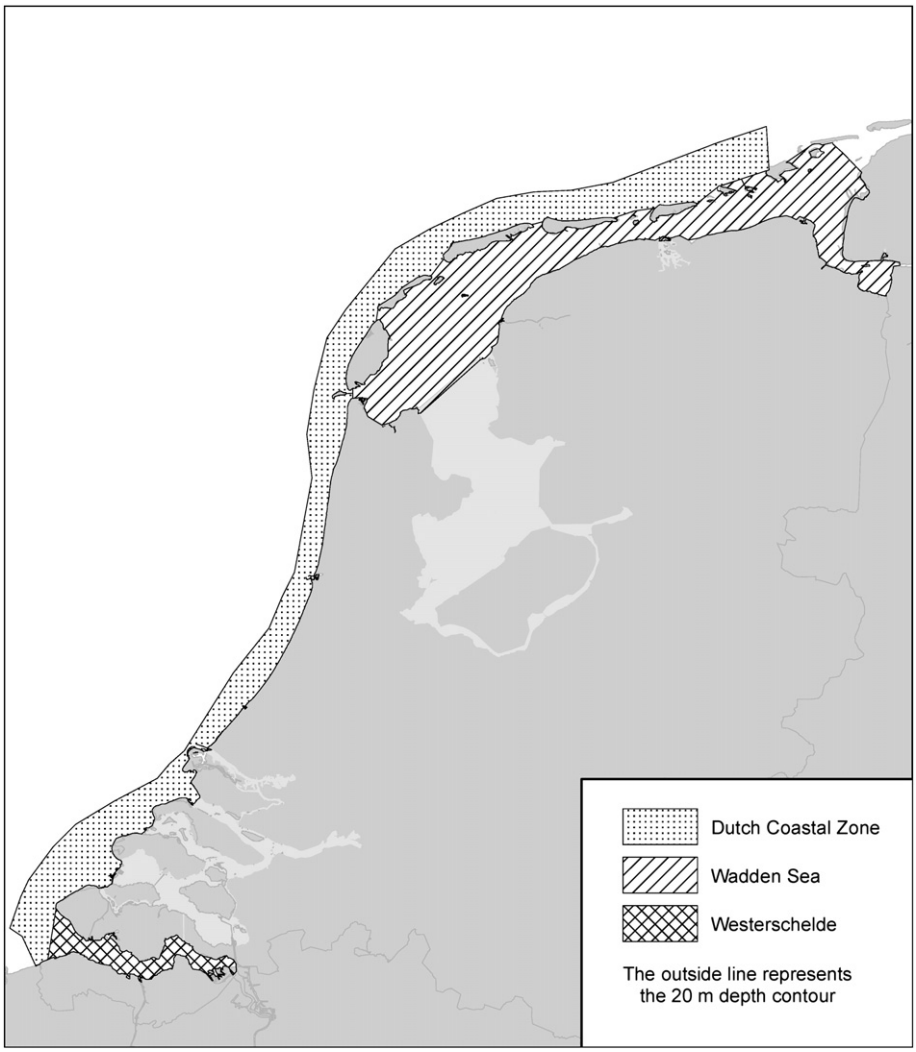

Fig. 1. The three coastal areas in the Netherlands used in this study.

that inhabit the Wadden Sea and Westerschelde year round. They entirely depend on the estuarine environment in all life stages. Most non-resident species leave in autumn and migrate to the deeper waters of the North Sea and return again in spring.

In addition to its natural dynamics, environmental characteristics in the coastal areas have changed considerably in the past decades. Long-term data series have shown that water temperature has increased (van Aken, 2003), a phenomenon that has been observed at North Sea scale as well (Becker and Pauly, 1996). Nutrient loads showed a peak in the seventies of the last century and decreased subsequently (Van Raaphorst and De Jonge, 2004). Especially in shallow areas such strong changes in environmental factors are expected to impact the ecosystem. Changes in primary production and bivalve recruitment (Cadee and Hegeman, 2002; Philippart et al., 2003; Philippart et al., 2007) and a change in the composition of the benthic community has been shown (Ens et al., 2004). Fish are in the middle of the food web, they feed on zooplankton and benthos and are eaten by predatory fish, birds and sea mammals. Depending on whether the abundance of fish is controlled top-down or bottom-up, they are likely to respond to changes in either food availability or predator abundance.

On top of changes in environmental conditions, also human activities such as shellfish fishing have impacted coastal waters (Piersma et al., 2001; van Gils et al., 2006). Until 1990 the cockle *Cerastoderma edule* fisheries was not limited by quota, between 1990 and 2003 it was more or less regulated and by 2005 it was