Estuarine, Coastal and Shelf Science 181 (2016) 284–293

Contents lists available at ScienceDirect

Estuarine, Coastal and Shelf Science

journal homepage: www.elsevier.com/locate/ecss

Long-term changes in species composition of demersal fish and epibenthic species in the Jade area (German Wadden Sea/Southern North Sea) since 1972

Julia Meyer [a,*], Ingrid Kröncke [a], Alexander Bartholomä [a], Joachim W. Dippner [b], Ulrike Schückel [a]

[a] Senckenberg am Meer, Dept. for Marine Research, Südstrand 40, 26382 Wilhelmshaven Germany
[b] Leibniz Institute for Baltic Sea Research Warnemünde, Seestraße 15, 18119 Rostock Germany

ARTICLE INFO

Article history:
Received 4 February 2016
Received in revised form
6 July 2016
Accepted 29 August 2016
Available online 31 August 2016

Keywords:
Epibenthos
Demersal fish species
Climate regime shifts
Southern North Sea

ABSTRACT

Within this long-term study, the short- and long-term variability of demersal fish and epibenthic species in relation to temperature and climate-driven environmental changes in the inshore tidal bay system of the Jade area was investigated. Semiquantitative sampling took place once per spring and summer period from 1972 to 2014 by using a 2 m beam trawl at one station in the Jade area (German Wadden Sea/southern North Sea). Min/max autocorrelation analysis (MAFA) and Mann-Kendall analysis revealed significant increasing trends in total abundance and species number. Homogeneity analysis revealed shifts for abundance in spring and summer in the late 1980s and for species number in the late 1980s in spring and early 2000s in summer. Abundances of the estuarine crustacean species *Carcinus maenas* and *Liocarcinus holsatus* and of the estuarine fish species *Pomatoschistus* spp. showed significant increasing abundances since the late 1980s. The marine juvenile species *Pleuronectes platessa* and *Limanda limanda* showed significant decreasing abundances, while abundances of *Solea solea* showed significant increasing abundances since the early 2000s. Abundances of *L. holsatus* and *C. maenas* showed mass occurrences since the early 2000s. Spearman correlation analysis revealed significant correlations of temperature and abundance data of some characteristic species. Statistical downscaling analysis revealed significant correlations between observations and climate indicators such as the North Sea Environmental (NSE) Index for spring. Thus, it appears that climate effects influenced the long-term variability of species number and abundance of epibenthic and demersal fish species in the Jade area, resulting in community shifts in the late 1980s and early 2000s.

1. Introduction

During the last decades significant changes in the entire North Sea ecosystem occurred in pelagic and benthic communities, and pelagic and demersal fish stocks (Reid and Edwards, 2001; Beaugrand et al., 2003; Luczak et al., 2012; Kröncke et al., 2013). Long-term studies, such as the present study, provide a valuable opportunity to detect and analyze the variability of ecosystem changes (Strayer et al., 1986). Several long-term studies revealed that changes in ecosystems are frequently linked to climate factors, including natural climate variability such as temperature anomalies e.g. cold winters, long-term climate trends or climate regime shifts (Reid and Edwards, 2001; Drinkwater et al., 2010; Kröncke et al., 2013). According to Kröncke et al. (1998) temperature is the mediator between climate and benthos. Since the 1970s, cold winters in the 1980s and in 1995/96 occurred, influencing benthic, pelagic and fish communities. Neumann et al. (2008, 2009) detected mainly short-term effects of cold winters on demersal fish and epibenthic species, with low abundances in cold winters followed by higher recruitment of several generalists.

Climate and/or anthropogenic induced changes, causing a reorganization of community structure, are described as biological regime shifts (BRS) (Reid and Edwards, 2001; de Young et al., 2004). There are no consistent definitions for BRS although Scheffer et al. (2001) defined three types of BRS: Within a *smooth* BRS there is a

* Corresponding author.
E-mail address: Julia.Meyer@senckenberg.de (J. Meyer).

http://dx.doi.org/10.1016/j.ecss.2016.08.047
0272-7714/

linear relationship between driver and response variable; an *abrupt* BRS is characterized through a non linear relationship; while within a *discontinuous* BRS there are alternative stable states. Next to temperature, climatic indices such as the North Atlantic Oscillation (NAO) Index, defined by Hurrell (1995) are often used as reference factor (Dippner et al., 2010; Kröncke et al., 2013; Beaugrand et al., 2014). In the North Sea several studies found a smooth BRS in 1988/89 (Weijerman et al., 2005) and a shift from a longer lasting negative NAO pattern to a positive NAO pattern with mild winters (Dippner et al., 2014), caused by an increased heat transport from the tropics to the extra-tropics (Hoerling et al., 2001). In 2000/2001 a global *climate regime* shift occurred (Swanson and Tsonis, 2009) coupled with an abrupt BRS (Kröncke et al., 2013; Dippner et al., 2014; Beaugrand et al., 2015).

Changes in abundance and distribution of demersal fish stocks were observed connected with temperature changes since the late 1980s in the whole North Sea (Hislop, 1996; Dulvy et al., 2008; Jager et al., 2009). The *gadoid outburst* occurred in the North Sea in the 1960s was caused by temperature induced changes in plankton communities and increased temperatures from the mid 1980s resulted in an ongoing decline of gadoid stocks in the southern North Sea, connected with a spatial shift in northern regions of the North Sea and the North Atlantic (Cushing, 1984; Hislop, 1996; Beaugrand et al., 2003). Changing distribution patterns of demersal fish species such as *Pleuronectes platessa* and *Solea solea* were recorded simultaneously to the development of gadoid species in the North Sea (Dulvy et al., 2008; Engelhard et al., 2011).

Within the last 25 years, there has been a sea surface temperature warming of 1.5 °C of Wadden Sea areas (van Aken, 2008). Marine communities in the southern North Sea and Wadden Sea areas are influenced by increasing temperatures due to low water depth and a well mixed water column. This results in higher temperature variability in that area, in contrast with the northern communities (Callaway et al., 2002).

The transitional Wadden Sea area, including coastal waters, is a highly dynamic environment that is strongly related to estuarine systems. As the Wadden Sea is adjacent to the North Sea, it is characterized by species, such as *P. platessa*, *L. limanda* or *S. solea.* These species use Wadden Sea areas during different stages of life, mainly as juveniles (Bolle et al., 2009). As consequence of spatial shifts of their adult populations in the North Sea, a change in abundances and use of Wadden Sea areas as nursery grounds occurred. van der Veer et al. (2015) found an essential decrease of juvenile demersal fish species in Wadden Sea areas within the last 50 years, due to increased water temperature, predation, habitat destruction or large-scale hydrodynamic circulation. In contrast, an increase in abundance of crustacean species such as *Carcinus maenas* were recorded in Wadden Sea areas since the late 1980s (Buhs and Reise, 1997). Highest landings of *Crangon crangon* were also recorded in Wadden Sea areas since the mid 2000s. These changes were caused by lower abundances of predatory gadoid species, due to temperature induced shifts and a higher fishing effort on this species (Siegel et al., 2005; Neudecker and Damm, 2006; Temming and Hufnagl, 2014).

This long-term study from 1972 to 2014 presents the annual variability of demersal fish and epibenthic species in the tidal bay system of the Jade area being part of the southern North Sea and the Wadden Sea. The Jade area is a miscellaneous habitat, used as long-term residence for estuarine fish species or crustacean species (Elliott and Dewailly, 1995), feeding grounds (McLusky, 1999) or nursery grounds e.g. for demersal fish species (Elliott and Dewailly, 1995; van der Veer et al., 2011).

One of the main objectives of the present study was to describe the annual variability of total abundance, species number and characteristic species in the Jade area within a time period of 42 years. In comparison with observed changes in the whole North Sea ecosystem we analyzed: (1) if temperature and total abundance and abundance of characteristic species correlate; (2) if trends and BRS in abundance and species number in relation to temperature can be shown, and (3) we compared climate effects found in the Jade area with other North Sea areas.

2. Materials and methods

2.1. Study site

The tidal bay system of the Jade area, located in the central part of the German Wadden Sea (Fig. 1), is part of the Senckenberg LTER North Sea Benthos Observatory. The Wadden Sea, as a part of the southern North Sea, is defined as a transitional area, implying the characteristics of an estuary system (Elliott and McLusky, 2002). It is characterized by low water depth and a high freshwater discharge e.g. at the Weser and Ems estuary leading to lower salinity <30. In contrast to real estuarine systems, tidal bay systems such as the Jade area are connected with adjacent marine systems via small straits without any freshwater discharge, and are strongly influenced by tides. A strait of 4.5 km connects the Jade bay towards the inner and outer Jade with the North Sea (Götschenberg and Kahlfeld, 2008).

2.2. Sampling

Long-term epifauna and demersal fish sampling were carried out from 1972 to 2014 on board RV “Senckenberg” with an average depth of 10 m in the inner Jade (Fig. 1). Each sampling was carried out with a 2 m beam trawl with a net and cod end mesh size of 1 × 1 cm and an attached tickler chain. Each haul was carried out for a distance of 1 NM at 2 knots (≈ 3740 m^2) (Blahudka and Türkay, 2002). Species were determined to species level and counted on board. Sampling took place twice a year in spring (April/May) and summer (August/September), depending on weather conditions. At each sampling one haul was taken. Sampling, equipment, and treatment has not changed since 1972.

2.3. Environmental parameters

Monthly sea surface temperature (SST) data of the Jade area from the Vareler Tief (VT 53°30′54″ N 08°10′65″ E) were used. For the correlation analysis average SST of January to March was used as winter, of April to June as spring, and July to September as summer. Winter North Atlantic Oscillation (NAO) Index was obtained from https://climatedataguide.ucar.edu.

2.4. Macrofauna data analysis

Total abundance, species number, and abundance of characteristic species are given per haul per season (spring and summer).

2.4.1. Temporal variability of total abundance, species number, and abundance of characteristic species

Temporal trends were analyzed by a min/max autocorrelation factor analysis (MAFA) and the non-parametric Mann-Kendall analysis for spring and summer. MAFA analysis was used to detect general trends for the whole community involving environmental parameters, while Mann-Kendall analysis was used for detecting trends separately for abundance, species number and abundance data of characteristic species. Shifts in total abundance, species number, and abundance of characteristic species were analyzed by using homogeneity analysis.