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An early footprint of fisheries: Changes for a demersal fish assemblage in the German Bight from 1902–1932 to 1991–2009

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ABSTRACT

Groundfish survey data from the German Bight from 1902–08, 1919–23, and 1930–1932 and ICES International Bottom Trawl Survey (IBTS) quarter 3 data from 1991 to 2009 were analysed with respect to species frequencies, maximum length, trends in catch-per-unit-effort, species richness parameters (SNR) and presence of large fish (Φ_{40}), the latter defined as average presence of species per haul with specimens larger than 40 cm given. Four different periods are distinguished: (a) before 1914 with medium commercial CPUE and low landings, $\Phi_{40} \approx 2$, high abundance in elasmobranchs and SNR conditions indicating highly diverse assemblages, (b) conditions immediately after 1918 with higher commercial CPUE, recovering landings, Φ_{40} at >4 in 1919, and SNR conditions indicating highly diverse assemblages, (c) conditions from 1920 to the early 1930's with decreasing commercial CPUE, increased landings, decreasing Φ_{40}, SNR conditions similar to later years indicating less diverse assemblages, and a decrease in elasmobranchs. In the IBTS series (d), Φ_{40} remains low indicating an increased rarity of large specimens, and SNR characteristics are similar to the third period. Dab, whiting and grey gurnard have increased considerably in the IBTS series as compared to the historic data. Φ_{40} is suggested an alternative indicator reflecting community functional diversity when weight based indicators cannot be applied.

1. Introduction

Long-term fisheries survey data sets are essential to indicate the development of fish stocks and environment in relation to human impacts and natural trends, and thus to assess the state of marine ecosystems as requested for by maritime environmental policies (e.g. EU Marine Strategy Framework Directive (2008/56/EU)). Survey data allow scientists to address changes not only on species but also on community level (Gifford et al., 2009; Greenstreet and Rogers, 2006), and size-based community level indicators are particularly effective in epitomizing changes in ecosystem state and functioning (Shin et al., 2005, 2010). The rationale for size-based indicators of ecosystem health is that large specimens of fish and large-sized species will be extracted as a direct effect of fishing on a disproportionably higher rate compared to small specimens and small-sized species, whereas small species might increase in abundance due to indirect effects such as reduced predation (Daan et al., 2005).

Only few data sets cover the period before 1945 in European maritime waters, and due to the short duration of historical sampling periods, provide a mere snapshot of the environment (McHugh et al., 2011; Rijnsdorp et al., 1996; Rogers and Ellis, 2000). But even the earliest available survey data reveal an already disturbed state of the marine environment since severe human impacts have been indicated long before routine surveys commenced in the early 20th century (e.g. Lotze, 2007; Sims and Southwood, 2006). Three historic North Sea data series have been published to date, i.e. Dutch southern North Sea data 1902 to 1909 (Rijnsdorp et al., 1996; ter Hofstede and Rijnsdorp, 2011), south-western North Sea data from 1903 off the British coast (Rogers and Ellis, 2000), and Scottish data from the north-western North Sea 1925–1953 (Greenstreet and Hall, 1996), providing the basis for the development of important ecosystem indicators (e.g. large fish indicator (LFI), Greenstreet and Rogers, 2006; ratio of northern to southern species, ter Hofstede and Rijnsdorp, 2011).

The data series presented here are from three distinct historical periods in the southeastern North Sea, i.e. 1902–08, 1919–1923 and 1930–32 (Fig. 1), and are compared with contemporary ICES survey data from 1991 to 2009 that cover a period of significant changes. Mean sea surface temperature (SST) from 1902 to 1932 was below, and after 1990 was above the long-term mean 1870–2002 (Wiltshire and Manly, 2004). Fishing effort increased considerably after 1919 and increased by a factor of 2.5 from 1924 to 1932 for all types of motorised bottom trawling in the entire area of the German Bight, while 17% of the area was untrawled before 1914. German annual landings almost tripled from before 1914 to the 1930's (Table 1). After 1945, fishing capacity of the North Sea fleets increased in general and for beam trawlers in particular (Engelhard, 2008), which were reintroduced to the mixed fisheries in the southeastern North Sea in the 1960's (Philippart, 1998; Rijnsdorp and Leeuwen, 1996). Accordingly, ter Hofstede and Rijnsdorp (2011)

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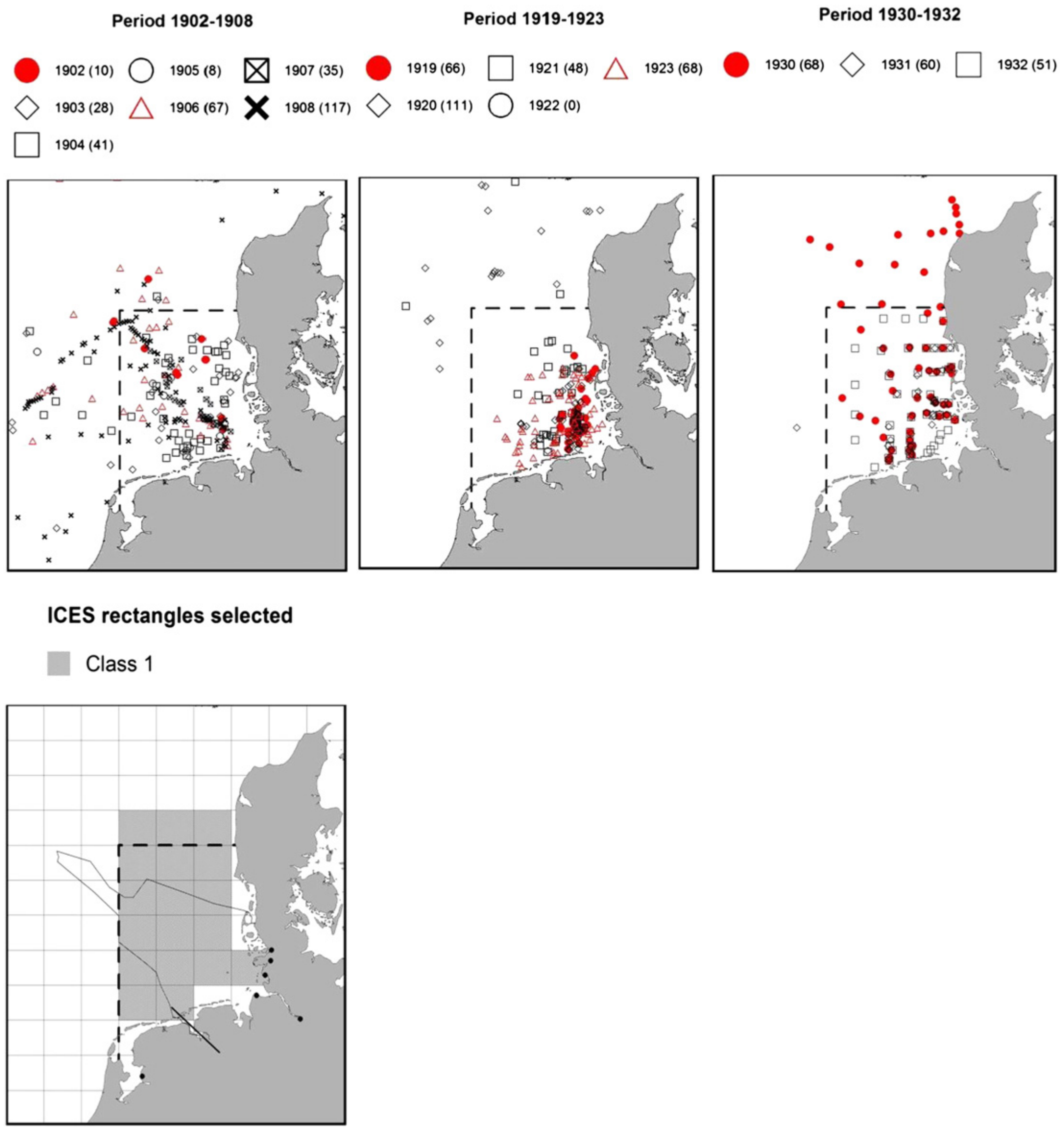

Fig. 1. Sampling designs in historic groundfish surveys in the German Bight in the southeastern North Sea for three periods 1902–08, 1919–223 and 1930–32, and ICES rectangles selected for the period 1991–2009 (class 1). Historic sampling positions by year indicated, numbers in parentheses show total number of hauls in that year in the entire North Sea. Hatched line indicates bounds for historical data at 5 °E and 56 °N.

characterized the period 1902–1908 by low ambient temperatures and relatively low fishing pressure, and the 1990's by warm conditions combined with high fishing pressure.

In total, historic data from 457 hauls presented here complement information on the poorly sampled interim period 1919 to 1932 in the North Sea, and add significant knowledge to fish assemblage structure prior to 1910 for a hitherto poorly sampled area, i.e. the German Bight representing the important flatfish fishing grounds at that time (Schnakenbeck, 1928).

The striking impression from examining old data is the number of large fish and the widespread presence of species presently found to be rare. Thus, to track changes in the ecosystem we develop and employ a suite of indicators comprising presence/absence (frequency), density-based measures (catch-per-unit effort, CPUE), diversity measures (structure of accumulation curves), size-based (e.g. maximum length by species) and one combined measure indicating the frequency of large species per sample. Diversity and the combined indicator refer to assemblage level, whereas all other indicators refer to species level.

Combining historic with contemporary data series is not trivial (e.g. Fock et al., 2002). In order to obtain robust indicators, methods are adopted to solve shortcomings due to incomplete length–frequency measurements, differences in catchabilities between series, differences in sample sizes and changes in spatial sampling designs. Trends in indicators are evaluated against catch statistics and multivariate patterns to account for contributions of individual species (use of MDS plots, Greenstreet and Hall, 1996, and references therein).

2. Material and methods

2.1. Fisheries surveys

Quarter 2 and 3 fisheries survey data including the main periods of fishing effort from May to September from 3 historical periods were available from surveys of FRV "Poseidon I" deploying an otter board trawl, i.e. 1902–1908, 1919–23 and 1930–32 (Table 2, Fig. 1, data at www.pangaea). These data were compared to data from quarter 3 ICES International Bottom Trawl Survey from 1991 to 2009, mainly carried out during August (see Rijnsdorp et al., 1996, data at www.ices.dk). Historical trawling speed was mainly indicated as 2 to 2.5 knots, towing duration varied from mainly 1–2 h prior to 1908 to mainly 30 min in 1932 (Table 3). For the purpose of analysing frequencies and maximum lengths survey data were not separated into day (n = 407) and night