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Wondering about wandering whiting: Distribution of North Sea whiting between the 1920s and 2000s

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ABSTRACT

The responses of fish populations to anthropogenic and environmental drivers are of growing interest. In commercial fisheries attention is increasingly directed to species historically being of secondary importance and potentially being influenced by these drivers. We present long-term commercial fisheries data of North Sea whiting (*Merlangius merlangus*), comprising international catches (1903–2010), quotas (1980–2010), and British otter trawler data (landings-per-unit-effort (*lpue*) for 1923–2009 at the spatial scale of ICES rectangles). Based on *lpue* data, we tested the possible effects of climate change and fishing pressure on whiting distribution. Results showed no distinct latitudinal and deepening shifts, but a ∼1° westward shift between the late-1940s and 1960s. Relations to climate change and fishing pressure were not strong. The lack of clear latitudinal and deepening shifts contrasts with recent studies on other North Sea species reporting such shifts related to temperature change. The North Sea is at the centre of the distribution range of whiting, and the temperature changes might still fall well within the physiological tolerance limits of this species, hence not affecting the distribution. The drivers for the longitudinal shift remain unclear. However, whiting is also commonly discarded by fisheries; if levels of discarding differ spatially, our results may not represent the true picture of whiting distribution and need to be interpreted with caution. This highlights the challenge in detection and attribution of climate change effects on exploited fish stocks with commercial data only.

1. Introduction

In recent years, North Sea whiting (*Merlangius merlangus*) has gained increased attention from fisheries management agencies, science and advisory organisations and the fishing industry. The status of the stock is considered unknown with respect to biological reference points as these are not defined (e.g. ICES, 2012). This has implications for stock management, increasing the demand for more information on this species. Further, lately the distribution and abundance of whiting became a matter of debate as findings of annual research surveys were not always corresponding with fishermen's perception (e.g. ICES, 2011a). In addition, the interest in whiting fisheries, historically of secondary commercial relevance (ICES-FishMap, http://ices.dk/marine-data/maps/Pages/ICES-FishMap.aspx), has increased. Despite whiting being one of the most abundant and widely distributed North Sea gadoids (Knijn et al., 1993), and undergoing a substantial decline in SSB since the 1980s (ICES, 2012), it is not as well studied compared to other commercially important gadoids such as Atlantic cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) (Web of Knowledge).[1]

High densities of both small and large whiting can be found in the entire North Sea, with the exception of the Dogger Bank, generally showing lower abundance (ICES-FishMap). On the basis of vertebral counts, tag-recapture data, and genetic analysis it has been suggested that two distinct whiting populations are distributed to the north and the south of the Dogger Bank (Charrier et al., 2007; Gamble, 1959; Hislop and MacKenzie, 1976; Williams and Prime, 1966). In the North Sea, whiting is caught in three areas (northern zone, off the eastern English coast, and the southern area extending into the English Channel) (ICES, 2008) and as part of the mixed demersal roundfish fisheries, fisheries targeting flatfish and

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[1] Number of citations in http://apps.webofknowledge.com for Atlantic cod + *Gadus morhua* 7484, haddock + *Melanogrammus aeglefinus* 927, and whiting + *Merlangius merlangus* 403, as of 16.04.2012.

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nephrops, and as bycatches in the industrial sandeel and Norway pout fisheries (ICES, 2011a). It is caught in large numbers, however, large quantities of the catch are discarded due to e.g. high-grading or once the species quota is reached (Catchpole et al., 2005; Cotter et al., 2002; Enever et al., 2009; Stratoudakis et al., 1999).

For commercial fisheries, distribution shifts of fish populations may have implications for the catchability of fish species. Fish stocks may move out of operating range for a country's fishing fleet or into areas with fishing restrictions (Pinnegar et al., 2010; Sumaila et al., 2011). A shift, expansion or contraction of a species' distribution can be caused by long-term changes in temperature (Brander et al., 2003; Cheung et al., 2009; Dulvy et al, 2008; Engelhard et al., 2011a; Keeken et al., 2007; Perry et al., 2005). However, not only climate change but also fishing pressure can influence long-term shifts of fish migration patterns, spawning grounds or a species' distribution (Engelhard et al., 2011b; Holst et al., 2002; Opdal, 2010). Long time series have been demonstrated to be useful for disentangling climate and fishing effects. Short time series have the disadvantage that these two variables are more likely to be confounded, but over a longer time period these drivers are more easily separable, allowing a distribution shift to be related to climate change or fishing pressure (Engelhard et al., 2011a).

This study aims to extend the knowledge regarding North Sea whiting, by analysing long-term data of international and British (England & Wales, Scotland) commercial fisheries. We present over 100 years' catch data of European countries and recent quota uptake rates, describing the trends of international whiting fisheries in the North Sea. Data from British otter trawlers on the spatial scale per ICES rectangle and covering nine decades were used to analyse the spatial distribution of British whiting landings in the North Sea. Further, based on the trawlers' landings-per-unit-effort (*lpue*), we analysed the long-term changes in whiting distribution. As the study's time span covers periods of warming and cooling in the North Sea, as well as different levels of fishing pressure, we attempted to disentangle relative influences of climate and/or fishing pressure on distribution shifts. Finally, the challenges in interpreting commercial fisheries data are highlighted.

2. Materials and methods

2.1. Fisheries data

Long-term data of international and British North Sea whiting catches as well as British *lpue* data were collated. To outline the development in whiting fisheries, over 100 years (1903–2010) of annual whiting catch data (for human consumption) of European countries were obtained from ICES statistics (ICES, 2010a, ICES, 2011b). These were available as Excel files (1903–1949) as well as a database on catch statistics (1950–2010), being extracted with the FishStat Plus programme (FAO, 2011). These data, and whiting quotas (after exchange) from 1980 onwards (provided by the Directorate-General for Maritime Affairs and Fisheries of the European Commission), were used to calculate the quota uptake rates. For the analysis of trends in British North Sea whiting landings and whiting distribution changes, nine decades of annual effort (hours fished) and landings (kg) data of British otter trawlers landing into England, Wales and Scotland were available for each ICES rectangle (0.5° latitude by 1° longitude). Historical statistical charts[2] (catalogued in Engelhard, 2005) were digitised containing records of landings into England & Wales and Scotland (1923–1938, 1947–1966) and landings into England & Wales (1967–1980). For the years 1968–2009, an electronic database for landings into Scotland was obtained from the Fisheries Management Database of Marine Scotland. For the years 1982–2009, data for landings into England & Wales were available from the Fisheries Activity Database held at the UK Department for Environment, Food and Rural Affairs (Defra). These data include mainly medium to large whiting because small whiting were typically not landed by these otter trawl fisheries, and minimum landing size regulations have been in force since 1970 (25 cm between 1970 and 1982 (MAFF, 1968), and 27 cm from 1983 onwards (EEC, 1983)). Juvenile, small whiting are therefore not captured in this analysis.

[2] Produced by the UK Ministry of Agriculture, Fisheries and Food (MAFF; now the UK Department for Environment, Food and Rural Affairs (Defra)).

2.2. Distribution of British whiting landings in the North Sea

Digitised historical data and recent electronic databases were merged to create one database covering nine decades of British otter trawler landings and effort by ICES rectangle. Landings, being recorded in hundredweights (1 cwt = 50.8023 kg) until 1972, were converted into kilograms. Mean decadal landings were calculated per ICES rectangle to demonstrate the distribution of British whiting landings in the North Sea.

2.3. Analysis of the spatial distribution of whiting

Lpue data by rectangle were analysed to illustrate long-term trends in the spatial distribution of whiting. The British North Sea trawl fisheries shifted from using steam otter trawlers (1923–1967) to motor otter trawlers (1957–2009), going along with improvements in fishing power and technical efficiency over time (Engelhard, 2008). To account for such an increase in fishing power of trawlers, the relative annual *lpue* value ($lpue'_{i,y}$) for each rectangle *i* and year *y* was calculated, taking variations across years in *lpue* into account:

$$lpue'_{i,y} = \frac{lpue_{i,y}}{(\sum_{i=1}^{N} lpue_{i,y})/N}$$

where $lpue_{i,y}$ represents the *lpue* values in rectangle *i* and year *y*, and *N* is the total number of rectangles in the defined study area. It was assumed that relative *lpue* values across the statistical grid indicate the spatial distribution of whiting.

To assess the long-term distribution shift of North Sea whiting, the 'centres of gravity' (COG) of the longitudinal, latitudinal and depth distribution were calculated. The analysis was adopted from the methods developed and applied by Heino et al. (2003) and used in Engelhard et al. (2011a). The defined study area only included rectangles with ≥50 h of fishing effort per year and a data coverage of ≥40 years (Fig. 1). To exclude data from statistical rectangles that were not adequately fished by the otter trawlers in any given year, any rectangles comprising no data or <50 h effort were removed from the analysis. This applied to 1558 out of the 11466 analysed rectangle-year combinations. Instead, the *lpue* in the given rectangle was assumed to be equal to the long-term mean *lpue* for the respective rectangle. To reveal the distribution shifts over time, the COG of the latitudinal distribution for each year was calculated:

$$\mathrm{COG} = \frac{\sum_{i=1}^{N} lpue_i \cdot lat_i}{\sum_{i=1}^{N} lpue_i}$$

where $lpue_i$ is the *lpue* for each rectangle *i*, lat is the latitudinal centre of each rectangle *i*, and *N* is the total number of rectangles.