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Entering uncharted waters: Long-term dynamics of two data limited fish species, turbot and brill, in the North Sea

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ABSTRACT

In the North Sea, turbot (*Scophthalmus maximus*) and brill (*Scophthalmus rhombus*) represent highly valuable species in commercial fisheries. Still, available data for both species are limited, making stock assessment difficult. Long-term fisheries data have the potential to improve the understanding of stock dynamics such as long-term distribution changes or development in species' abundances. Historical British otter trawler lpue (landings-per-unit-effort) data from 1923 to 2009, and at the spatial scale of ICES rectangles, revealed that the distribution patterns of turbot and brill were different for most of the 20th century and only became similar in the recent decade. Further, between the 1920s and 1960s, turbot was commonly caught in the northern North Sea and in particular on Turbot Bank, at that time a turbot hotspot off the east coast of Scotland. Within a short time period turbot nearly disappeared from this region. Brill, in contrast, revealed a stable distribution in the southern and central North Sea with a slow expansion into the central North Sea. We used survey cpue (catch-per-unit-effort) from the International Bottom Trawl Survey (IBTS; 1970–2009) and the Beam Trawl Survey (BTS; 1985–2009), as well as British otter trawler lpue, as proxies for the abundance of adult turbot and brill. Commercial lpue suggested for brill and turbot a long-term decrease in abundance. IBTS cpue suggested an increase in abundance for turbot, but this was not confirmed by the BTS. For brill, both surveys did not show a clear trend.

1. Introduction

Good fisheries policy and fisheries management should be based on sound scientific information about the state of fish stocks. However, worldwide most commercially exploited fish stocks are not assessed (Costello et al., 2012). In the Atlantic, North Sea and Baltic Sea, the proportion of stocks where no scientific advice is available rose from 45% in 2003 to 52% in 2006 and then fell again to 36% for 2012 (EU, 2012). Even for fish stocks that are assessed, their assessments are based on short time-series that are generally less than three decades long (Pinnegar and Engelhard, 2008). Historical data can give new opportunities to improve the knowledge and development of fish stocks in recent decades and even centuries (e.g. MacKenzie et al., 2002; Poulsen, 2010; Poulsen et al., 2007). Long time-series may allow scientists to better understand exploitation patterns of fisheries or stock dynamics and can help to disentangle environmental influences (e.g. climate change) and fishing pressure on fish stocks. Additionally, historical fisheries data also help create baselines of the state of fish stocks (Pauly, 1995; Pinnegar and Engelhard, 2008).

Historical commercial fisheries and/or survey data that are stored in archives in many fisheries departments and laboratories are useful in reconstructing long-term time-series. Only in recent years, scientists started to discover and unveil historical datasets to understand long-term changes in diversity, distribution and abundance of marine life in the world's oceans (e.g. Cardinale et al., 2009; Cheung and Sadovy, 2004; Lescrauwaet et al., 2010; Rosenberg et al., 2005). In the United Kingdom, the Centre for Environment, Fisheries and Aquaculture Science (Cefas) holds historical fisheries data in their archives of North Sea commercial fisheries, going back around 100 years. In recent years, effort was made to recover and digitise these historical paper charts, providing scientists the opportunity to analyse population dynamics of various exploited North Sea fish species.

Turbot (*Scophthalmus maximus*) and brill (*Scophthalmus rhombus*) are regarded as data limited fish species, with available information being inadequate to evaluate stock trends, making stock assessments and advice difficult (ICES, 2011a). Although both species are mainly caught as bycatch, discarding is low because of their high market prices, and therefore they are economically important for fisheries (Gillis et al., 2008). Turbot and brill grow relatively fast, in particular juvenile turbot reaches approximately 30 cm by the age three. Both are piscivorous in the adult stage and are found in similar depth ranges (brill 4–73 m,

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turbot 10–70 m) along the European coastline. Brill occurs mainly in areas close inshore and preferring sandy bottoms, but can sometimes be found on gravel and muddy grounds. Turbot prefers sandy, rocky or mixed bottoms (ICES, 2010a) and is a rather sedentary species. There are some indications of migratory patterns from the nursery grounds in the south-eastern North Sea to the more northern areas, as adult turbot are more tolerant of the colder conditions in the northern North Sea where temperatures are too low for juveniles to survive (Delbare and de Clerck, 2000; ICES, 2010a). Despite an intensive exploitation of turbot ($F = 0.5$–0.7), there is no indication that turbot recruitment is impaired at low levels of spawning stock biomass (van der Hammen et al., 2013–in this volume). So far, spatial distribution maps of North Sea turbot and brill are available for recent decades and are based on survey data (see http://ecosystemdata.ices.dk).

In this paper, we aim to evaluate the changes in catches, distribution and abundance of North Sea turbot and brill in the 20th century. Specifically, we collate historical long-term data of European countries fishing in the North Sea to understand the development of international landings from the 1900s to the present. We further reveal long-term distribution changes of turbot and brill based on nine decades of British otter trawler landings-per-unit-effort (lpue) at the spatial scale of ICES rectangles. Finally, we assess the abundance dynamics of both species based on British otter trawlers' lpue and two North Sea surveys' catch-per-unit-effort (cpue).

2. Materials and methods

2.1. International landings data for brill and turbot, 1903–2010

To give an overview of the development of North Sea turbot and brill fisheries international landings data for turbot and brill in the North Sea were obtained from ICES, (2010b, 2011b). Specifically, catch statistics were available as Excel files (1903–1949) as well as an electronic database (1950–2010), the latter being extracted with the FishStat Plus programme (FAO, 2011). In the ICES database, Dutch records for turbot were missing for the years 1984–87. This also applied to brill, where as well the years 1988–89 were considered unreliable. For these years, data were obtained from the Report of the Working Group on Assessment of New MoU Species (WGNEW) (ICES, 2012).

2.2. British lpue data by rectangle, 1923–2009

To evaluate the spatial distribution of turbot and brill in the North Sea, we analysed British otter trawlers lpue data between 1923 and 2009. Annual effort (hours fished) and landings (kg) data of turbot and brill landed into England, Wales and Scotland were available for each ICES rectangle (0.5° latitude by 1° longitude). Historical statistical charts[1] (catalogued in Engelhard, 2005) were digitised, containing records of effort and landings into England & Wales and Scotland (1923–1965), and into England & Wales (1966–1980). For 1968–2009, data on effort and landings into Scotland were obtained from the Fisheries Management Database of Marine Scotland. For 1982–2009, data for England & Wales were available from the Fisheries Activity Database (Defra/Cefas, 2010). The combined time-series covered the years 1923–2009 (war years 1939–1946 were missing).

2.3. Research survey data

International Bottom Trawl Survey (IBTS) for turbot and brill were available as "cpue per length per haul" from the ICES DATRAS webpage (http://datras.ices.dk/Home/default.aspx). The IBTS covers the entire North Sea, and data collected from all ships, gears and sampled quarters were analysed from 1970 onwards. The Beam Trawl Survey (BTS) is a specialised flatfish survey operating since the mid-1980s and sampling the shallower waters of the southern and central North Sea, but not the deeper northern North Sea. Data from the RV Isis (source IMARES, pers. comm. J.J. Poos) were analysed, as the most consistent information regarding the BTS is provided from this research vessel (pers. comm. J.J. Poos, and see Heessen, 2010), which operates in the eastern parts of the southern and central North Sea.

2.4. Spatial distribution of turbot and brill based on British lpue

Analysis of spatial distribution of turbot and brill in the North Sea was conducted using commercial otter trawler lpue, following the methodology used in Kerby et al. (2013) With steam trawlers (1923–1967) gradually being replaced by motor trawlers (1957–2009), the effect of increasing fishing power over time was taken into account. Therefore, the relative annual lpue values ($\text{lpue}'_{r,y}$) were calculated for each rectangle r and year y and were assumed to be an indicator for the spatial distribution of turbot and brill:

$$\text{lpue}'_{r,y} = \frac{\text{lpue}_{r,y}}{\left(\sum_{r=1}^{N} \text{lpue}_{r,y}\right)/N}$$

where $\text{lpue}_{r,y}$ represents the lpue values in rectangle r and year y, and N is the total number of rectangles in the study area. The defined study area only included rectangles with ≥50 hours of fishing effort per year and a data coverage of ≥40 years. For rectangles not meeting these thresholds, instead the relative lpue (lpue') in the given rectangle was assumed to be equal to the long-term mean lpue' for the respective rectangle.

2.5. Trends in abundance

Commercial mean annual lpue and survey cpue were used as proxies for abundance. Commercial mean annual lpue was calculated from statistical rectangles that met the minimum fishing effort and data coverage thresholds. For the IBTS and BTS, data within the defined study area were used to calculate the mean annual cpue of turbot and brill. IBTS data were available from ICES with standardised cpue ("number-per-hour"), separated by length-class (cm). For the analysis of BTS data, only hauls ≥25 min were included, which were converted to "number-per-hour" for each length class. Although no official minimum landings size has been set, part of the fisheries in the North Sea adopted a voluntary minimum landing size of 30 cm (ICES, 2011a). Thus, both survey data were filtered by a minimum length size of 30 cm.

The BTS and IBTS cpue data were converted from length to weight to allow comparison with the commercial data that were reported in "kg-per-hours-fished" by applying published length-weight conversion equations: $W_{\text{brill}} = 0.0078 \cdot L^{3.1947} \cdot 1.0487$ and $W_{\text{turbot}} = 0.0039 \cdot L^{3.397} \cdot 1.0643$ (Coull et al., 1989), where W is the total weight (kg), and L the length (cm). Total catch (converted into weight from length) per haul, year and statistical rectangle was calculated, and the mean annual cpue per year was calculated for both species.

In order to test whether lpue was correlated with cpue in the overlapping time periods (IBTS 1970–2009, BTS 1985–2009), we used Spearman's rank correlation (r_s) as not all variables were normally distributed (one-sample Kolmogorov–Smirnov test, $p > 0.05$).

3. Results

3.1. International landings data for brill and turbot, 1903–2010

In the time periods 1900s–1940s and 1970s–2000s, total international landings of turbot and brill showed a similar trend (Fig. 1). Turbot,

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