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Population ecology of turbot and brill: What can we learn from two rare flatfish species?☆

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ABSTRACT

Turbot and brill are widely distributed in the Northeast Atlantic but occur at low abundance. They are ecologically very similar and closely related. The low abundance and the similarities make them particularly interesting to study the population dynamics because it raises the questions how the populations can sustain themselves at low abundances and how turbot and brill avoid strong interspecific competition. Knowledge of both species is hampered by lack of analysed data. The main objective of this study is therefore to increase the knowledge of turbot and brill and in particular to compare the two species in order to address the above questions. Based on biological samples collected in the North Sea, we calculated seasonal von Bertalanffy growth parameters, maturity ogives, monthly gonado-somatic indices (GSI) and condition factors (Fulton's K) and indices of inter- and intraspecific mean crowding and compared the results for turbot and brill. The main differences between the two species were found in their spawning period, with brill having a more protracted spawning period. Brill also showed an earlier peak in their GSI values, suggesting an earlier start of their spawning period. The mean crowding showed that inter-specific competition was lower than intraspecific competition. The exploitation pattern was also studied. Turbot and brill are exploited as a bycatch species in the mixed demersal fishery. We found that productivity is highest in areas where the maximum temperature is close to the optimal temperature for growth (16–18 °C) and landings decrease where salinity falls below ~5 psu (turbot) and ~15 psu (brill). Recent fishing mortality rates of North Sea turbot are around 0.5–0.7, but there is no indication that recruitment is impaired at low levels of spawning stock biomass. We conclude that although both species have similar ecological characteristics, differences may reduce inter-specific competition.

1. Introduction

One of the fundamental questions in population biology is what determines the population size (Krebs, 1972). The processes that determine the population size may differ in relation to the position within the geographic distribution range. Miller et al. (1991) proposed a framework on the latitudinal patterns and the processes involved. Towards the polar side of the distribution, abiotic factors tend to dominate, whereas biological interactions dominate on the equatorial side. Another important factor is the availability of suitable habitat. In sole (*Solea solea*), a positive correlation was shown between population size and the surface area of nursery grounds across populations of common sole, suggesting that nursery habitat size might be a bottleneck determining the population abundance (Rijnsdorp et al., 1992). A similar relationship was found in Icelandic plaice (van der Veer et al., 2000) and may explain the differences in abundance across species living in the same geographical area (Gibson, 1994). The particular importance of the nursery grounds for flatfish may be related to the concentration phase in many flatfish species that occurs when the pelagic larvae settle in specific nursery habitats (Beverton, 1995).

Turbot (*Scophthalmus maximus*) and brill (*Scophthalmus rhombus*) are ecologically similar species that occur in relatively low abundance throughout their distributional range (Whitehead et al., 1986). Both species inhabit shallow soft bottom habitats where they feed on crustaceans and fish. Pelagic eggs are spawned offshore and larvae are transported by wind-driven currents to the surf zone of sandy beach nurseries (Riley et al., 1981; van der Land, 1991). Early demersal juveniles are restricted to the shallow sandy grounds on exposed shores (Besyst et al., 1999; Nissling et al., 2007; Riley et al., 1981). Variation in 0-group abundance across beaches and inter-annual variation in abundance may be related to variations in the transport of larvae towards the inshore nursery grounds (Haynes et al., 2011b; Nissling et al., 2006; Sparrevohn and Stottrup, 2008). Large specimens can be observed to a depth of about 100 m (Knijn et al., 1993; Kerby et al., 2013–in this volume). The ecological similarity of turbot and brill raises

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the question whether the species differ in some characteristics to avoid competition.

The population dynamics of turbot and brill are particularly interesting to study because their low abundance may be informative about the minimum number of adult fish producing sufficient recruits to sustain the population. In fisheries management, the minimum spawning stock biomass is often pragmatically defined as the lowest level at which there is no sign of recruitment failure. In the period 1950–2000, demersal trawling in the North Sea has strongly increased, which may affect turbot and brill (Kerby et al., 2013–in this volume). Because of the low stock sizes, turbot and brill may be more vulnerable to potential Allee effects, compared to stocks that occur in higher abundance. At low stock sizes, for example, the number of adults may be too low to find a mate, hampering successful reproduction (Frank and Brickman, 2000; Stephens and Sutherland, 1999).

Low abundance often results in lack of data, which makes it difficult to study the population dynamics. Turbot and brill are exceptions because their high market value makes them important bycatch species in mixed bottom trawl fishery. Usually, turbot and brill are not targeted but in the North Sea turbot may be targeted by gillnetters (Vinther, 1995) and sometimes by beam trawlers (Gillis et al., 2008). In the Baltic, turbot is targeted in a gillnet fishery (Draganik et al., 2005; Stankus, 2003). Since 2000, annual catch quotas are imposed by the European Commission. Although routine fisheries data are being collected on turbot and brill, neither species has attracted much research effort. A better understanding of the population ecology of these two rare flatfish species may indicate how many adults are required for sustainable production of recruits.

The main objective of this paper is to review and analyse the available data on turbot and brill to increase the general knowledge of these species. In addition, the paper attempts to answer two main research questions: (1) how can two closely related ecologically similar low-abundance flatfish species coexist together?; and (2) is there reason to be concerned about the states of the turbot and brill stocks? We start with an analysis of the distribution, growth and reproductive biology of the North Sea turbot and brill populations and estimate the biomass, recruitment and exploitation rate of turbot. The analysis is based on data collected from landing statistics, market samples taken from the commercial landings and from several demersal fish surveys. These surveys cover most of the distribution of turbot and brill in the North Sea and include different size classes. Subsequently, the productivity of the North Sea stock is compared to the productivity of other stocks in the North-east Atlantic. Results are discussed in light of latitudinal differences in population regulation, with particular focus on the hypothesis that the size of the nursery area determines population abundance.

2. Material and methods

2.1. Data sources

2.1.1. Data from beam trawl surveys

A number of beam trawl surveys were carried out to monitor flatfish and other demersal fish populations in the North Sea. All surveys took place in the period August to October, except for the beach survey which was carried out throughout the year. Each survey was designed for a specific depth zone and size range of demersal fish.

Beach surveys were conducted in the coastal waters of the Netherlands between 0.5 and 7 m depth using a 2-metre beam trawl from a rubber dingy (mesh size 5 × 5 mm; haul duration 5–15 min). The survey was conducted in different months between 1974 and 1985 and in 2011 (n = 643 hauls; Bolle et al., 1994). In addition, 1-metre pushnet samples (n = 75 hauls; 74.1 m^2 swept area) were obtained in the surf zone at ~50 cm depth between 1979 and 1983.

The *Demersal Fish Survey* (DFS) is a yearly survey sampling in the 3 nautical mile coastal zone along the Dutch, German and Danish coast (from the southern Dutch border to Esbjerg: 6 m shrimp trawl) and the estuaries of the Schelde, Wadden Sea and Ems-Dollard (3 m shrimp trawl) since 1970 (n ≈ 250 hauls $year^{-1}$; mesh size 35 × 35 mm; towing speed 2.5 knots; haul duration 15 min; van Beek et al., 1989).

The *Sole Net Survey* (SNS) is a yearly survey, sampling the coastal zone along the Dutch, German and Danish coast (from Hoek van Holland to Esbjerg, up to ~30 nm) offshore using a 6 m beam trawl since 1970 (n ≈ 70 hauls $year^{-1}$; mesh size 40 × 40 mm; towing speed 3.5 knots; haul duration 15 min; van Beek, 1997).

The *Beam Trawl Survey* (BTS) is a yearly survey, sampling the offshore waters of the North Sea (south eastern part since 1985; central part since 1996) with an 8 m beam trawl (n ≈ 150 hauls $year^{-1}$; mesh size 40 × 40 mm; towing speed 4 knots; haul duration 30 min; Bogaards et al., 2009; Rogers et al., 1998; http://datras.ices.dk/Documents/Manuals/Manuals.aspx).

2.1.2. Catch and effort statistics

International landing data for turbot and brill were available through the Eurostat database and were downloaded from http://www.ices.dk (Dec 2012). This database holds the officially recorded landings for all countries by ICES (International Council for the Exploration of the Sea) management area (Table 1). For the North Sea, landing data were available for each year since 1903. There were no records for the Dutch landings in the Eurostat database between 1984 and 1987. However, for the North Sea these missing landings were estimated based on confidential reports from fish auctions (Boon and Delbare, 2000; ICES, 2012).

Landings and effort data from the Dutch fleet were obtained from EU (European Union) logbooks and the market category composition of landings was obtained from auction sale slips. Official EU logbook data of the entire Dutch fleet were maintained by the NVWA (Netherlands Food and Consumer Product Safety Authority, formerly known as the General Inspection Service, AID) and contain information on (i) landings by vessel, trip, ICES statistical rectangle and species; (ii) effort (days absent from port) by vessel, trip and ICES statistical rectangle, calculated from trip departure and arrival time; and (iii) vessel information on engine power and gear used. Logbook data were available for the entire Dutch commercial fishing fleet and for foreign vessels landing their catches in the Netherlands.

2.1.3. Market sampling data

Turbot and brill landings of commercial fisheries were sampled on a quarterly basis during the periods 1980–1990, 1998, and 2004–present, from randomly selected vessels at the major auctions in the Netherlands. For each vessel sampled, the landings were recorded and the length distribution was determined. Biological data was collected from a subset of the sampled vessels and processed in the laboratory to record gender, size (cm), age (years, birthdate 1 Jan), gutted weight, maturity stage (immature, ripening, spawning, spent) and gonad weight of females. The number of fish sampled was about 10 000 turbot and 5000 brill.

2.1.4. Environmental data

Temperature and salinity data were obtained from the ICES Oceanographic database. Monthly mean bottom temperature and annual mean salinity (psu) were calculated for each ICES (sub)area from all stations between 10 and 50 m depth.

The surface areas of bathymetric zones by ICES (sub)area were obtained from http://topex.ucsd.edu/cgi-bin/get_data.cgi. The size of the nursery grounds was approximated as the surface area of the depth zone of 0–2 m. The size of the adult habitat was estimated as the surface area of the depth zone of 2–50 m.

2.2. Methods

2.2.1. Condition factors

In order to compare seasonal changes in the condition of the total body and of the gonads of brill and turbot, we calculated Fulton's