In Collaboration with the Royal Netherlands Institute for Sea Research

Journal of Sea Research 57 (2007) 187 – 197

JOURNAL OF SEA RESEARCH

www.elsevier.com/locate/seares

Changes in the spatial distribution of North Sea plaice (*Pleuronectes platessa*) and implications for fisheries management

O.A. van Keeken *, M. van Hoppe, R.E. Grift, A.D. Rijnsdorp

Wageningen IMARES, Institute for Marine Resources and Ecosystem Studies, P.O. Box 68, 1970 AB IJmuiden, The Netherlands

Received 29 October 2005; accepted 25 September 2006
Available online 28 October 2006

Abstract

To protect the main nursery area of plaice, an area called the 'Plaice Box' was closed to trawl fisheries with large vessels in 1989, with the expectation that recruitment, yield and spawning stock biomass would increase. However, since then the plaice population has declined and the rate of discarding outside the Plaice Box has increased, suggesting an offshore shift in spatial distribution of juvenile plaice. Using research vessel survey data collected since 1970, the change in distribution of juvenile age groups was analysed in relation to the distance to the coast. Further, a comparison of the distribution of different length classes of plaice between three historic periods was made (1902–1909; 1983–1987; 1999–2003). A shift towards deeper water of larger-sized plaice (20–39 cm) is apparent already before the 1980s and may be related to the decrease in the number of competitors or predators. An offshore shift in the distribution of young plaice occurred in the 1990s most likely in response to higher water temperatures that may have exceeded the maximum tolerance range or increased the food requirements above the available food resources. A decrease in competition with larger plaice offshore, possibly in combination with increased inshore predation by cormorants and seals, may also have played a role. The offshore shift in distribution has reduced the effectiveness of the Plaice Box as a technical measure to protect the under-sized plaice from discarding, since an increased proportion of the population of undersized plaice is moving to the more heavily exploited offshore areas.

Keywords: Plaice; Spatial distribution; North Sea; Plaice Box; Fisheries management

1. Introduction

In the North Sea, plaice is exploited in a mixed fishery for flatfish. Due to the small mesh size used in the fishery to catch sole, large numbers of undersized plaice are caught and discarded (Rijnsdorp and Millner, 1996; Van Beek, 1998). In order to reduce discard mortality, the main distribution area of undersized plaice was closed to fishing in 1989 for vessels with an engine power of more than 300 hp (221 KW) (ICES, 1994, 1999). This area, the 'Plaice Box', was based on the spatial segregation between juvenile and adult fish (ICES, 1987, 1994). Plaice spawn in offshore waters, whereas the juveniles settle in the shallow waters of estuaries and sandy beaches. During ontogeny, plaice gradually leave the shallow coastal waters and move into deeper waters further offshore (Wimpenny, 1953; Rijnsdorp and Van Beek, 1991).

In contrast to expectations, the recruitment, yield and spawning stock biomass of plaice decreased since the introduction of the Plaice Box (ICES, 1999). The rate of

* Corresponding author.
E-mail address: Olvin.van.Keeken@wur.nl (O.A. van Keeken).

1385-1101/$ - see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.seares.2006.09.002

discarding in the waters outside the Plaice Box has increased (ICES, 1999; Pastoors et al., 2000), and plaice have been discarded at smaller lengths outside the Plaice Box in recent years (own obs.), suggesting that a change in the distribution pattern of plaice may have occurred.

The distribution pattern of plaice is the result of the interaction between behaviour through directed migrations and small-scale (dispersive) movements, and the effect of fishing. Migratory behaviour between summer feeding areas and winter spawning areas develops when plaice becomes sexually mature (De Veen, 1978; Rijnsdorp, 1989; Rijnsdorp and Pastoors, 1995; Gibson, 1997; Hunter et al., 2003). Small-scale movements will occur in the juvenile and adult phase. Such small-scale movements may be random (Beverton and Holt, 1957), for example as a result of foraging behaviour, may have a directed component, for example in the tidal migrations (Kuipers, 1973; Gibson et al., 2002) or, when related to the evasive behaviour, may be directed away from adverse environmental conditions such as extreme temperatures or low oxygen concentrations (Beverton and Holt, 1957; Berghahn et al., 1993; Gibson, 1994, 1997). Beverton and Holt (1957) described the offshore movement of plaice as a dispersion process, thus driven by random movements. Small-scale directed movements were described by Berghahn et al. (1993), who recorded a mass exodus of 0-group plaice from the tidal flats in response to temperature. Also, the autumn offshore migration from the shallow inshore waters and the spring inshore migration may reflect a response to temperature and feeding conditions (De Veen, 1978). Fish may further respond to predation risk by changing migration behaviour (Burrows and Gibson, 1995; Manderson et al., 2004). Offshore movement could also be an effect of changed feeding conditions, caused by the introduction of the Plaice Box, since fishing efforts shifted to the border of the Plaice Box after its closure. Bottom trawling may increase the availability of the benthos in terms of suitable food for plaice (De Veen, 1978; Rijnsdorp and Van Beek, 1991; Rijnsdorp and Vingerhoed, 2001).

A change in the distribution of undersized plaice may have a large impact on the management of the fisheries. Insight into the extent of the changes in distribution and the likely causes is of paramount interest for the evaluation of the effectiveness of the current management of the Plaice Box.

This paper focuses on the offshore movement of plaice from the nursery grounds along the continental coast. These nursery areas produce 90% of the recruitment of North Sea plaice (ICES, 1985; Van Beek et al., 1989). Changes in distribution are analysed in relation to the distance to the continental coast, using research vessel survey data collected since 1970. Further, a comparison is made of the distribution of different length classes of plaice between three historic periods: 1902–1909, 1983–1987 and 1999–2003, and implications of the change in distribution for fisheries management are discussed.

2. Methods

2.1. Comparing spatial distribution between three historic periods

The spatial distributions of different size classes of plaice were compared between three periods: 1902–1909, 1983–1987, 1999–2003. The periods analysed differed with respect to several of the factors that may affect distribution, such as water temperature, productivity, predation risk and the level and distribution of fishing effort.

2.1.1. Data

Third quarter data for 1902–1909 were available from two different surveys: RV ‘Huxley’ and RV ‘Wodan’. References to these data can be found in Rijnsdorp et al. (1996). RV ‘Huxley’ used either a 26.5 m otter trawl (OT90) or a 13 m beam trawl (BT13) (Table 1). Tow duration varied between 1 and 3 h at a towing speed of 2 nm h^{-1}. Fish were grouped into 10 cm length classes. RV ‘Wodan’ used a 26.5 m otter trawl similar to that of RV ‘Huxley’. Haul duration was generally 1–2 h at a towing speed of 2 nm h^{-1}. Fish were grouped into 5 cm length classes. Mesh size was 63 mm and 68 mm for beam trawl and otter trawl, respectively.

Table 1
Details of the gears used during 1902–1909, 1983–1987 and 1999–2003

	BT13 1902–1909	OT90 1902–1909	BT14 1983–1987	BT12 1983–1987	BT8 1983–1987 1999–2003
Haul duration (min)	60–180	60–180	10–40	10–40	30
Codend mesh	63	68	85	85	40
Tickler chains	0	0	8	8	8
Towing speed	2	2	5–5.5	5–5.5	4
Sweep	13	17	14	12	8
Swept area (1000 m^2 h^{-1})	50	60	140	120	60
Relative catch effiency	0.85	1	2.3	2	1

Relative catch efficiency rates were standardized to swept area per hour with OT90/BT8.