Journal of Sea Research 120 (2017) 13–23

Contents lists available at ScienceDirect

Journal of Sea Research

journal homepage: www.elsevier.com/locate/seares

Variability and connectivity of plaice populations from the Eastern North Sea to the Baltic Sea, part II. Biological evidence of population mixing

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ARTICLE INFO

Article history:
Received 19 January 2016
Received in revised form 7 November 2016
Accepted 17 November 2016
Available online 19 November 2016

Keywords:
Plaice
Pleuronectes platessa
Skagerrak
Kattegat
North Sea
Stock identity
Connectivity
Lumping
Splitting
Genetics
Growth
Hydrodynamic model
Tagging

ABSTRACT

A multi-disciplinary study was conducted to clarify stock identity and connectivity patterns in the populations of European plaice (*Pleuronectes platessa*) in the Skagerrak-Kattegat transition area between the Eastern North Sea and the Baltic Sea. Five independent biological studies were carried out in parallel. Genetic markers suggested the existence of different genetic populations in the transition area. Growth backcalculation with otoliths resulted in significant although limited differences in growth rates between North Sea and Skagerrak, indicating weak differentiation or important mixing. Hydrogeographical drift modelling suggested that some North Sea juveniles could settle along the coast line of the Skagerrak and the Kattegat. Tagging data suggested that both juveniles and adult fish from the North Sea perform feeding migrations into Skagerrak in summer/autumn. Finally, survey data suggested that Skagerrak also belongs to the area distribution of North Sea plaice. The outcomes of the individual studies were then combined into an overall synthesis. The existence of some resident components was evidenced, but it was also demonstrated that North Sea plaice migrate for feeding into Skagerrak and might constitute a large share of the catches in this area. The mixing of different populations within a management area has implications for stock assessment and management. Choice must be made to either lump or split the populations, and the feasibility and constraints of both options are discussed. The outcomes of this work have directly influenced the management decisions in 2015.

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1. Introduction

Issues of stock identification have wide implications for conservation, when management areas are not matched with the distribution of biological populations. This well-known topic has long been a major focus in fisheries science (cf. reviews in e.g. Begg et al., 1999; Cadrin and Secor, 2009; Reiss et al., 2009; Stephenson, 1999; Ying et al., 2011), and uncertainties on the actual population boundaries likely occur for most fish stocks. The awareness on this issue is further reinforced by the current concerns on distributional shifts linked to climate change (Link et al., 2011), and by the ever-evolving methods on stock identification (Cadrin et al., 2013) which provide a much more detailed knowledge on differences in populations at a fine geographical scale.

The European plaice (*Pleuronectes platessa*) is no exception in this domain. Plaice stock structure comprises different spawning components, which separate during spawning and mix during feeding. Juveniles of different spawning components mix also partly on nursery grounds (Hufnagl et al., 2013; Hunter et al., 2004; Kell et al., 2004). The North Sea plaice is the largest stock defined, but its connectivity with the smaller surrounding areas has long been questioned. In particular, the stock structure in the transition area between the saline North Sea and the brackish Baltic Sea has long remained unclear and no sound scientific basis for fisheries management could be developed. This transition area is characterised by very heterogeneous hydrogeographical conditions with regards to depth, salinity and currents, with steep gradients over short distances (Fig. 1), and it is therefore increasingly recognised that these conditions contribute to a high, but complex structuration of many marine populations (Bekkevold et al., 2011; Limborg et al., 2009) and of the many fisheries that exploit them. Incidentally, the complexity of this transition area is also reflected in the multiple names and geographical identifications commonly used, which deserve clarification (Fig. 1). The entire area is referred to as Area IIIa by the International Council for the Exploration of the Sea (ICES). It is constituted of two administrative sub-areas, The Skagerrak

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http://dx.doi.org/10.1016/j.seares.2016.11.002
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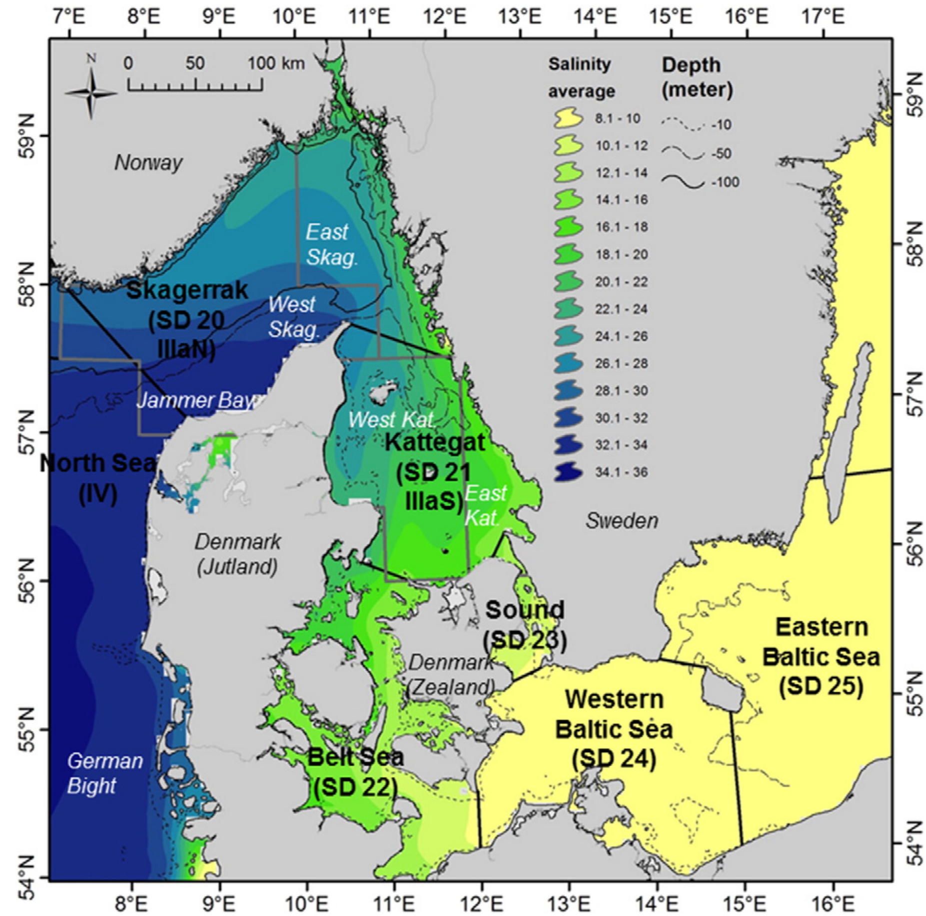

Fig. 1. Hydrographical map of the area with average surface salinity and depth, updated from Ulrich et al. (2013). The black straight lines delimitate the management areas. The grey lines delimitate the Eastern and Western areas of Skagerrak (Skag.) and Kattegat (Kat.) as suggested by ICES (2012).

in the Northwest (= ICES IIIa North) and the Kattegat in the Southeast (= ICES IIIa South). These two sub-areas are, however, also sometimes referred to following the Baltic Sea Sub-Division (SD) nomenclature, where the Skagerrak corresponds to SD 20 and Kattegat corresponds to SD 21.

A first synthesis of knowledge was undertaken by Ulrich et al. (2013). That initial study challenged the prevalent assumption that plaice in the Skagerrak and in the Kattegat belong to the same entity. Plaice populations in the two areas had traditionally been assessed together, but with poor and unreliable outcomes, and no analytical advice had been given for the combined area since 2002. Using the existing information at the time, Ulrich et al. (2013) performed a comprehensive review of all available biological knowledge on plaice in this area, including published and unpublished literature as well as analyses of commercial and survey data and historical tagging data. The results suggested that plaice in the Skagerrak is closely associated with plaice in the North Sea, although local populations were suspected to be present in the area. Plaice in the Kattegat, the Belt Sea and the Sound was also to be considered a separate stock unit, as was plaice in the Baltic Sea. Following that earlier study, the basis of the scientific management advice formulated by the International Council for the Exploration of the Sea (ICES) was changed accordingly (ICES, 2012). It became possible to reliably assess the plaice in the Kattegat, the Belt Sea and the Sound (a stock referred to as “plaice in SD 21–23”, ICES 2015c) using a standard age-based model. However, uncertainty remained for the largest fishery component of this transition area, the Skagerrak. Age-based models applied on catch data from this area still failed to deliver proper assessment outcomes, suggesting a violation of the basic assessment assumption of an isolated population. Management advice could only be given on the basis of a biomass survey index from the most westerly part of the area (“West Skagerrak”, Fig. 1), where most of the fisheries occur and where most of the mixing with the North Sea is assumed to take place (ICES, 2015e).

In spite of these progresses, the study by Ulrich et al. (2013) underlined nevertheless that the information available was fairly scarce and often old, and that many uncertainties remained. The alternative hypotheses on stock structure could not be fully ascertained. This absence of clear conclusions stopped further steps to be taken towards improved assessment and management. Furthermore, new issues in the approach agreed by ICES (2012) soon appeared. A closer investigation of the West Skagerrak biomass index revealed high variability between survey hauls and a strong stratification of plaice densities according to depth and longitude (ICES, 2015d). While stratification is a common feature in many marine populations and a well-known issue for the estimation of statistically sound abundance indices, this issue is particularly difficult to handle in this case because of the limited size of the area (hence a limited number of survey hauls) and of the steep depth gradient along the continental slope (Fig. 1).

It became evident that collecting new data was necessary to progress on the biological understanding of the population structure of plaice in this small but economically important area. The present study is thus the direct follow up of the previous work by Ulrich et al. (2013). In line with the most up-to-date multi-disciplinary approaches to stock identification methods (Cadrin et al., 2013; ICES, 2015a), new genetic, otoliths growth and hydrodynamic modelling data were collected and analysed between 2013 and 2014, together with a more in-

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