



The German Bight (North Sea) is a nursery area for both locally and externally produced sprat juveniles

Hannes Baumann^{a,*}, Arne M. Malzahn^b, Rudi Voss^c, Axel Temming^d

^a School of Marine and Atmospheric Sciences, Stony Brook University, Stony Brook, NY, 11794-5000, USA

^b Alfred Wegener Institute for Polar and Marine Research, Biologische Anstalt Helgoland, Building A, Ostkaje 1118, 27498 Helgoland, Germany

^c Department of Economics, Sustainable Fishery, University of Kiel, Wilhelm-Seelig Platz 1, 24118 Kiel, Germany

^d Institute of Hydrobiology and Fisheries Sciences, Olbersweg 24, 22767, Hamburg, Germany

ARTICLE INFO

Article history:

Received 20 October 2008

Received in revised form 29 December 2008

Accepted 8 January 2009

Available online 22 January 2009

Keywords:

Nursery Area

Otolith Microstructure Analysis

Egg Production

Larval Production

Helgoland Roads

Temperature–Growth Relationship

ABSTRACT

To better understand the role of the German Bight (GB) as a nursery area for juvenile North Sea sprat *Sprattus sprattus* we sought to determine whether the area may receive only locally or also externally produced offspring. We sampled juveniles during 3 trawl surveys in the GB in August, September, and October 2004 and applied otolith microstructure analysis in order to reconstruct their distributions of the day-of-first-increment-formation (*dif*). These were contrasted with spatial and seasonal patterns of sprat egg abundance in the GB and its adjacent areas, observed during 6 monthly plankton surveys. It was found that the majority of juveniles originated mainly from April/May 2004, coinciding with high spawning activity west of the GB, whereas spawning and larval production *inside* the GB peaked notably later, in May/June. This indicated that a large proportion of juveniles was produced *outside* the GB and transported subsequently into it through passive and/or active migration. Shifts to later mean *difs* from one survey to the next and length distributions indicative of the simultaneous presence of multiple cohorts, supported the notion that the GB is a complex retention and nursery area for sprat offspring from different North Sea spawning grounds and times. Later born juveniles had significantly faster initial growth rates than earlier born conspecifics, which was likely temperature-mediated, given the strong correlation between back-calculated growth histories and sea surface temperature as a proxy for thermal histories of juveniles ($r^2 = 0.52$).

© 2009 Elsevier B.V. All rights reserved.

1. Introduction

Coastal regions often act as nursery areas for the larval and juvenile stages of marine fish. Such areas typically (i) show an enhanced primary and secondary production promoting cohort growth and hence survival (Anderson, 1988), (ii) receive offspring from other spawning areas due to passive larval transport, and (iii) have hydrographical features that favour offspring retention. Exploring the structure, function, and importance of nursery areas is in many ways highly relevant; for our general comprehension of ecosystems (including their potential need of protection from human exploitation, e.g., fishing), or specifically for understanding the dynamics of a particular fish population. The latter is because in most fish species juvenile survival variability (generated in nursery areas) significantly contributes to recruitment variability (Bradford, 1992; Leggett and DeBlois, 1994; Baumann et al., 2006a), which in turn is the dominant source of fluctuations in fish abundance (Sissenwine, 1984; Heath, 1992).

The German Bight (GB) in the south-eastern North Sea has long been recognized as a nursery area for juveniles of many commercially

important fish species, which are most abundant there between spring and fall (e.g., Clupeidae (Alshut, 1989), Gadidae (Berghahn, 1996), Pleuronectidae (Berghahn and Purps, 1998)). The GB is known for its high levels of primary and secondary production (Tillmann et al., 2000) resulting from nutrient enrichment due to coastal upwelling, tidal mixing, and river outflow (Krause et al., 1986). The counter-clockwise residual circulation in the southern North Sea (Otto et al., 1990, Fig. 1) provides a plausible mechanism for pelagic offspring transport towards the GB, while the Bights retentive circulation likely helps aggregating them in the area (Bartsch and Knust, 1994).

Sprat, *Sprattus sprattus*, a small, zooplanktivorous clupeid that occurs in high abundance in the southern North Sea, is one of the temporally dominant juvenile species in the GB (ICES, 2007). Sprat spawns pelagic eggs mainly between March and August (Munk, 1993) in a potentially broad range of southern North Sea areas (Aurich, 1941; Johnson and Dawson, 1975; Munk 1991a; Fig. 1). Spawning may be triggered by rising spring temperatures (Alshut, 1988a), since it appears to follow a characteristic spatio-temporal dynamic, commencing earliest in the English Channel region, then progressively later in more eastern areas and latest in the GB. It has been suggested (Alshut, 1988a) but never conclusively demonstrated that these reproductive patterns combined with the residual eastward current in the southern North Sea can result

* Corresponding author. Tel.: +1 631 632 3137.

E-mail address: hannes.baumann@stonybrook.edu (H. Baumann).

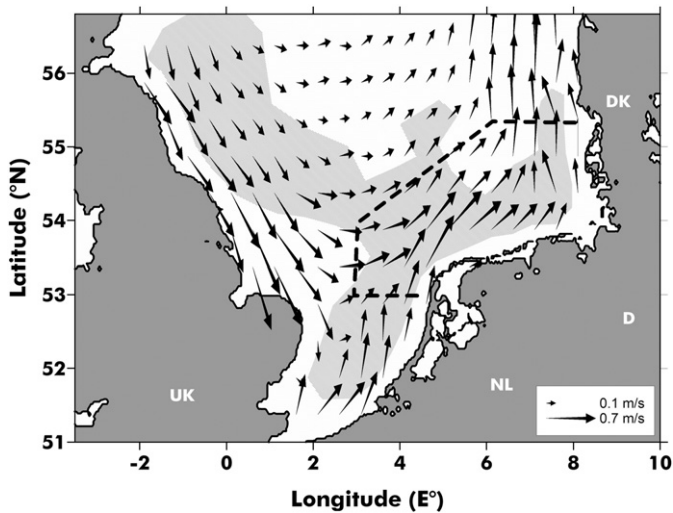


Fig. 1. Map of the North Sea, showing sprat spawning areas (hatched areas, modified after Munk (1991a)) based on historical accounts from Aurich (1941) and Johnson and Dawson (1975). Arrows depict the depth-integrated, mean residual circulation in April/May 2004 as predicted by the Hamburg Shelf Ocean Model (HamSOM, Pohlmann, 2006). The surveyed area is enclosed by the dashed line. D – Germany, DK – Denmark, NL – Netherlands, UK – Great Britain.

in an aggregation of sprat juveniles from different spawning areas and times in the GB. Such knowledge, however, is a first necessary step towards evaluating the GB's importance as a sprat nursery area. Of equal interest are the processes that shape the population of survivors prior and while juveniles occupy the GB. For example, knowledge about the potential presence, source, and direction of selective mortality, as well as about how environmental conditions influence larval and juvenile growth, is needed to better describe the role of the GB in the pre-recruit part of the sprat life cycle.

Our study was carried out in 2004, and focused on these three major lines of investigation, i.e. (i) the spatial importance of the GB, (ii) potential evidence for selective mortality and (iii) temperature-dependent growth of sprat juveniles in the GB. The three objectives were approached by using otolith microstructure analysis, which has previously proven to be a powerful research tool not only in studies on sprat larvae (e.g., Munk, 1993; Ré and Gonçalves, 1993; Valenzuela and Vargas, 2002), but also on older juveniles (Alshut, 1988a, 1989; Baumann et al., 2006b). This is because sprat form readily discernible, daily otolith increments starting around the time of first feeding (Alshut, 1988b) until at least their first winter (Baumann et al., 2006b). While the number of increments approximates age in days, otolith increment widths are known proxies for somatic growth rates, and hence useful to reconstruct individual growth histories (Stevenson and Campana, 1992).

We first asked whether sprat juveniles that occurred in summer 2004 in the GB were of local and/or external origin (i.e., spawned inside and/or outside the GB, respectively). Our approach was to compare otolith-derived distributions of the juveniles day-of-first-increment formation (*dif*, the best available proxy for hatch day) with the abundance of sprat eggs measured monthly during the spawning season in the GB and its adjacent areas (Figs. 1 and 2). Our null hypothesis was that sprat juveniles in the GB were entirely of local origin, which would be indicated if temporal egg abundance patterns in the GB would closely match the *dif* distribution of juveniles.

Secondly, we studied whether changes in length and growth rate distributions (back-calculated from otoliths) would point to a selective disappearance of certain phenotypes from one survey to the next. Assuming that sampling targeted roughly the same population over time, selection on – say – fast growth (large size-at-age) would be distinguishable from random mortality by an upward shift in the lower percentiles of the increment widths distribution

from one survey to the next (e.g., Baumann et al., 2003; Shoji and Tanaka, 2006; Robert et al., 2007).

Finally, weekly sea surface temperatures (SST) in the southern North Sea were used as proxies for juvenile thermal histories, which were correlated to back-calculated larval and juvenile growth rates. Temperature is known to be the most important abiotic growth determinant in fish larvae (Heath, 1992) and its intrinsic relationship to growth therefore a key characteristic for a given fish population.

2. Materials and methods

2.1. Juvenile sprat sampling and otolith analysis

Juveniles were sampled in the GB (i.e., 53°30'N, 6°30'E and 55°30'N, 8°30'E) during 3 consecutive surveys in August, September, and October 2004 (Table 1). Two similar pelagic trawl nets (August: EXPO; September/October: 'Juvenile Pelagic Trawl', 16/10 mm stretched cod end meshes, respectively) were deployed and assumed to representatively catch juvenile fish ≥ 5 cm TL (according to selectivity estimates by Bethke et al., 1999). Hauls were conducted at daylight hours, lasted approximately 30 min, and covered the depth strata where hydro-acoustic backscatter indicated the presence of fish. From each catch that contained a sufficient amount of sprat, an approximately 10 kg sub-sample was stored at -20°C .

In the laboratory, TL and SL (standard length) of sprat juveniles were measured to the nearest mm, prior to removal of the sagittal otoliths. Because of earlier age readings, specimens >90 mm were considered to be age 1 or older (J-P Herrmann, unpublished data; Munk, 1991b). Otolith preparation and microstructure analysis followed the methods described in Baumann et al. (2006b). Briefly, individually mounted otoliths (Crystallbond[®] 509 thermoplastic glue) were manually polished from both sides with a 3 μm lapping film (266x Imperial PSA 3M[®]) until all micro-increments were sufficiently visible along the core-postrostrum axis. An image analysis software (ImagePro 4.5.1) was then used to count and measure (μm) individual increments in multi-frame digital images, which were taken under 400 \times magnification with a high-resolution digital camera (Leica[®] DC300). Sufficient ageing precision has previously been confirmed via within- and across-reader comparisons as reported by Baumann et al. (2006b). A total of 193 individuals from 29 hauls were available for the present analysis (Table 1).

An iridescent check-mark, found at an average distance of 8.3 μm (SD = 1.2 μm) from the otolith core, was assumed to correspond to the day of hatch. The day of first increment formation (*dif*) was derived by subtracting the number of all increments (hatch check to postrostrum) from the sampling date. No correction was made for the difference between hatch date and *dif* (~5–10 days, Alshut (1988b), Peterit et al. (2008)), given the unknown thermal history of sprat juveniles during their egg and yolk sac stage.

The average juvenile length distribution of each survey (= average of each hauls relative distribution for specimens <90 mm TL) was used to correct for potential over- or underrepresented length classes in the sub-samples selected for otolith analyses. For every 5 mm TL class, the length frequency from the otolith sample was divided by the corresponding frequency from the field. This ratio was then assigned as a weighing factor to each analyzed specimen and used later for correction of TL, *dif*, and increment width distributions. Weighing factors at the extremes of the distributions ranged between 0.08 (too many otoliths read in a length class) and 4.2 (too few otoliths read), whereas for the main length classes (55– <85 mm TL) they were close to 1 (mean = 1.08).

2.2. Objective 1: Local vs. external origin of sprat juveniles

Here, otolith-derived age data of juveniles (*dif*-distributions) were contrasted with spatio-temporal patterns in sprat egg and larval

Download English Version:

<https://daneshyari.com/en/article/4550219>

Download Persian Version:

<https://daneshyari.com/article/4550219>

[Daneshyari.com](https://daneshyari.com)