Short communication

Estimation of mackerel (Scomber scombrus L., 1758) and horse mackerel (Trachurus trachurus L., 1758) daily egg production outside the standard ICES survey area

Leonie Dransfeld, Oonagh Dwane, John Molloy, Sarah Gallagher, and Dave G. Reid

An experimental egg survey was carried out to assess whether there was significant spawning of mackerel and horse mackerel outside the area surveyed triennially by the international mackerel and horse mackerel standard egg survey. In all, 170 stations were sampled in May 2002 on the Porcupine, Rockall, and Hatton Banks, over the Rockall Trough, and in Faroese waters, with 38 control stations inside and 132 stations outside the standard survey area. There was some spawning of mackerel south and east of the Rockall Bank and southeast of the Faroe Bank, extending to west of the Scottish Shelf. Limited horse mackerel egg production was found west of the Rockall Bank and south of the Faroe Bank. The total mackerel and horse mackerel daily egg production estimated from samples collected in 2002 outside the standard survey area was low compared with the egg production estimated in adjacent waters just inside the standard area in the same year and during the international standard surveys in May and June of 2001. The results suggest that including the spawning activity of both species outside the standard survey area would not significantly contribute to the total estimated egg production.

Keywords: daily egg production, ichthyoplankton, offshore banks, Scomber scombrus, spawning-stock biomass, Trachurus trachurus.

Introduction

The spawning-stock biomass of the Northeast Atlantic mackerel stock is estimated by calculating annual egg production and converting this value to biomass using fecundity measurements and sex ratios (Lockwood et al., 1981). ICES coordinates a triennial survey programme that covers the mackerel and horse mackerel spawning grounds from the Portuguese coast to north of Scotland throughout their spawning season from January to July.

Estimation of spawning-stock biomass is based on the assumption that the entire spawning stock is contained in the survey area. Early records on European mackerel spawning grounds in the late 1930s showed that mackerel spawned in the eastern Celtic Sea, with an eastward progression of spawning during the season (Corbin, 1947). In 1967, an extensive egg survey was carried out covering the west of Ireland and Scotland, extending to the Rockall and Rosemary Banks (Walsh, 1976). The survey revealed highest mackerel egg concentrations along the 200-m isobath on the Porcupine Bank, and west of Ireland and Scotland. Some mackerel spawning was also detected on the Rockall Bank, in the Rockall Trough, and on Rosemary Bank. The first ICES international Mackerel and Horse Mackerel Egg Surveys in 1977 showed that spawning was concentrated on the shelf edge and remained there throughout the spawning period (Lockwood et al., 1981). Subsequent triennial egg surveys followed the same survey area with sampling effort concentrated along the shelf edge. During the first three survey years in 1977, 1980, and
1983, sampling was carried out from the Bay of Biscay to 55°N. During that period, the location of spawning grounds remained relatively constant, with most stage 1 mackerel eggs found along the shelf edge southwest of Ireland. This consistency was seen despite the fact that there were noticeable changes in the distribution and migration of the adult population (Walsh and Martin, 1986). Additional egg surveys in 1986 and 1987 explored the area north of Ireland and west of Scotland for spawning activity, and revealed a small but significant proportion of mackerel spawning north of 55°N (Molloy and Barnwall, 1988), resulting in the international survey being extended to 60°N. This extension of the survey area helped to capture the geographic changes in mackerel spawning during the subsequent decade, because peak spawning shifted westwards and northwards (Bez et al., 1995; Reid, 2001; Beare and Reid, 2002).

In order to ensure coverage of the entire spawning ground, the survey design has been made more adaptive since 1995, whereby shipboard evaluation of egg abundance is used to direct sampling effort (ICES, 1996). The standard survey area adopted by the ICES Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS) broadly represents the area where mackerel and horse mackerel spawning would be anticipated along the European shelf edge between Portugal and Scotland. The western and eastern peripheries are adapted by extending transects until no eggs or two stations of low egg counts (fewer than 20 stage 1 eggs of either species) are encountered; the northern and southern areas can be extended by adding transects when eggs are found. This sampling design allows flexibility around the periphery of the general sampling area, but it does not account for egg production outside the general sampling area if it is separated from the main area by areas of zero production. As total survey time is fixed, complete detection of spawning limits is not always possible, and sampling positions are ultimately a compromise between time constraints and sampling effort adaptability. This means that some spawning activity can remain undetected and as a consequence will not be incorporated into the biomass estimate. To investigate the scale and potential impact of any unsurveyed spawning areas, an experimental egg survey was carried out, which covered potential spawning grounds outside the area sampled routinely. Additional sampling was conducted within the standard area to allow comparison with survey results from previous years. Here, we report the results of this experimental survey and discuss their implications for estimating spawning-stock biomass.

Methods

The experimental ichthyoplankton survey was carried out on the MFV "Atlantean" between 28 May and 16 June 2002, when mackerel spawning was assumed to be at its peak (Bez and Rivoirard, 2001). The sampling area covered the Porcupine, Rockall, and Hatton Banks, the Rockall Trough including the Anton Dohrn Seamount, and the Rosemary Bank, and extended north into Faroese waters (Figure 1). The sampling design consisted of a series of east-west transects, with plankton samples collected in the centre of rectangles of 0.5° latitude by 0.5° longitude. In all, 132 stations were sampled outside the standard survey area, and 38 sampled inside the area. Samples were collected and processed in accordance with the ICES international Mackerel and Horse Mackerel Egg Survey protocols (ICES, 2002). The samples were collected with a Gulf 7 plankton sampler deployed on an oblique tow at a speed of 4.5 knots, from the surface to 200 m or to within 5 m of the bottom in shallower water (<200 m), then returned to the surface. A real time CTD sensor (Pronet) was attached to the Gulf 7 to record depth, temperature, and salinity profiles for each deployment. Internal and external flowmeters monitored flow rates, volume filtered, and extent of net clogging. Plankton samples were preserved in 4% buffered formaldehyde and subsequently searched for fish eggs and larvae. Mackerel and horse mackerel eggs were identified, counted, and staged into the six and five developmental stages recognized for each species, respectively. Daily egg production was calculated according to ICES standard protocols (ICES, 1999, 2002).

Numbers of fish eggs per sample were converted to egg density \( S \) (per m²):

\[
S = \frac{N}{V} \times D
\]

where \( N \) is the number of eggs in the sample, \( V \) the volume of water filtered (m³), and \( D \) is the sample depth (m).

To calculate daily egg production \( P \) (m⁻² d⁻¹), stage 1 mackerel and horse mackerel egg densities \( S_1 \) were raised by applying the equation

\[
P = \frac{24 \times S_1}{\exp[a \log(T_{20}) + b]}
\]

using the species-specific parameters given by Lockwood et al. (1977) for mackerel \( (a = -1.61; b = 7.76) \), and by Pipe and Walker (1987) for horse mackerel \( (a = -1.68; b = 7.713) \). \( T_{20} \) is the temperature (°C) measured at 20 m.

Daily egg production was then raised to a value for the corresponding ICES rectangle:

\[
P_{\text{rectangle}} = P \left[ \cos \left( \frac{\phi}{180} \times \pi \right) \times 30 \times 1853.2 \right] \times (30 \times 1853.2)
\]

where \( \phi \) is the latitude at the centre of the rectangle in which the sample was taken.

Standard errors of the means were estimated by non-parametric bootstrapping, whereby samples were randomly re-sampled with replacement (1000 replications).
Figure 1. Mackerel daily egg production (m$^{-2}$ d$^{-1}$). (a) Experimental survey in 2002, (b) peak production in May 2001 for comparison. The shaded area represents the standard ICES survey area. Letters correspond to locations mentioned in the text: CS, Celtic Sea; RT, Rockall Trough, RB, Rockall Bank; HB, Hatton Bank; PB, Porcupine Bank; RM, Rosemary Bank; AD, Anton Dohrn Seamount; WTR, Wyville-Thompson Ridge; FB, Faroe Bank.
Results

During the experimental 2002 survey, highest rates of mackerel daily egg production were encountered at the peripheries of the standard survey area, at the edge of the Porcupine Bank and between the Scottish shelf edge and the Anton Dohrn Seamount. Rates of egg production were low outside the standard survey area in the Rockall Trough and at some stations south and west of the Rockall Bank (Figure 1a). More importantly, there were consistent observations of low egg production north of the standard area across the Wyville-Thompson Ridge. For comparison, Figure 1b shows daily mackerel egg production rates obtained during the same month of the standard 2001 international egg survey. Average production rates inside the standard area in the control rectangles in the experimental survey in 2002 were lower than in 2001, but of the same magnitude (Table 1). Total daily egg production for mackerel estimated outside the standard survey area in 2002 was just 0.4% of the egg production estimated inside the standard survey area in 2001 in May and 1.1% of that in June (Table 2).

Horse mackerel eggs were found in 14 hauls situated west of the Rockall Bank and south of the Faroe Islands, with highest daily egg production off the Faroese Shelf (Figure 2a). There was no egg production in the control rectangles inside the standard area. In May and June of 2001, spawning of horse mackerel was restricted to south of 54°N, moving northwards in July (Figure 2b). It is therefore likely that spawning in 2002 had also been located farther south of the area covered in the experimental survey. Estimated total horse mackerel daily egg production outside the standard area in 2002 was <0.2% of the total production estimated inside the standard survey area in 2001 in both May and June (Table 2).

Discussion

In order to use the ICES international Mackerel and Horse Mackerel Egg Surveys for estimating spawning-stock biomass, there has to be confidence that the entire spawning stock is contained within the survey area. Historical research has shown that the spawning area of mackerel does change, and therefore it is important that survey practice be reviewed in the light of the knowledge of such changes. Exploratory surveys such as the present one help to confirm that the survey is planned appropriately, or to make changes if required.

The survey reported here aimed to explore whether spawning of either mackerel or horse mackerel continues farther west and north than the standard area, specifically to the offshore banks such as Rockall and Hatton, and the Faroese Plateau. Although small concentrations of mackerel eggs, including recently spawned stage 1 eggs, were found in these areas, their combined egg production estimate was <1% of the egg production measured inside the standard area in the same month, but in the previous year (2001). Comparing the egg production of a single egg survey in 2002 with a series of surveys in 2001 poses problems, because it has to be assumed that the timing of peak spawning, its geographical location, and its magnitude did not change significantly between the two years. The experimental survey in 2002 actually showed a lower level of egg production inside the standard area than in 2001, based on the average production values and the distribution maps. Despite these uncertainties, the data obtained by the experimental survey suggest that spawning outside the

Table 1. Mean daily egg production estimates of mackerel in control rectangles inside the standard survey area in 2001 and 2002, and outside the standard survey area in 2002.

<table>
<thead>
<tr>
<th>Survey</th>
<th>Year and month</th>
<th>Mean mackerel daily egg production (m⁻² d⁻¹)</th>
<th>s.e.</th>
<th>Number of observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICES standard</td>
<td>2001 May, June</td>
<td>27.93</td>
<td>4.74</td>
<td>38</td>
</tr>
<tr>
<td>Experimental, inside standard survey area</td>
<td>2002 May, June</td>
<td>9.99</td>
<td>2.74</td>
<td>38</td>
</tr>
<tr>
<td>Experimental, outside standard survey area</td>
<td></td>
<td>0.38</td>
<td>0.099</td>
<td>132</td>
</tr>
</tbody>
</table>

Table 2. Comparison of 2001 and 2002 estimates of mackerel and horse mackerel daily egg production inside and outside the standard survey area. Estimates for 2001 are the sum of sampled and extrapolated rectangles; those for 2002 are the sum of sampled rectangles.

<table>
<thead>
<tr>
<th>Survey</th>
<th>Year and month</th>
<th>Sum of daily mackerel egg production (m⁻² d⁻¹)</th>
<th>s.e.</th>
<th>Sum of daily horse mackerel egg production (m⁻² d⁻¹)</th>
<th>s.e.</th>
<th>Number of observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>2001 May</td>
<td>2.02E+13</td>
<td>2.39E+12</td>
<td>1.27E+13</td>
<td>1.84E+12</td>
<td>319</td>
</tr>
<tr>
<td>Standard</td>
<td>2001 June</td>
<td>7E+12</td>
<td>7.21E+11</td>
<td>7.6E+12</td>
<td>1.34E+12</td>
<td>236</td>
</tr>
<tr>
<td>Experimental, outside standard survey area</td>
<td>2002 May, June</td>
<td>8.01E+10</td>
<td>1.96E+10</td>
<td>1.5E+10</td>
<td>9.15E+09</td>
<td>132</td>
</tr>
</tbody>
</table>
standard area does not contribute significantly to total egg production of either species, and supports the assumption that the area covered by the ICES international survey programme generally contains the main spawning-stock biomass. The experimental survey does, however, highlight the fact that the northern periphery of spawning has not yet been clearly defined, because some mackerel and horse mackerel spawn as far north as 62°N, south of the Faroe Islands and across the Wyville-Thompson Ridge, and perhaps even farther north. In the light of this finding,
a similar exploratory survey to the present one should ideally be carried out in this northern area, an area, including its possible continuity into the North Sea, which is of special interest because the North Sea spawning component of mackerel showed a marked increase in 2002 (ICES, 2003).

Acknowledgements

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References