Demographic connectivity of sardine in the Bay of Biscay and Iberian coast region


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Questions relevant for fisheries management

• What is the origin of sardine appearing in non-recruitment areas, such as North Spain and South Portugal?
• How strong is the dependency between areas?
• What drives connectivity between areas?
• May one stock help to recover the other stock?
• Are there actually two stocks?
Development of the stocks

NUMBER, billions

RECRUITS, billions

Year

Cohort
Objectives

• Investigate the dispersal of cohorts across the region
• Explore effects of cohort strength, density and environmental conditions on dispersal
Data

• Abundance-at-age in spring acoustic surveys
• Catch biomass and catch-at-age
• Satellite-derived SST and Chl $a$

2000 – 2016
DATA DISAGGREGATED IN 8 AREAS:

BISC - Bay of Biscay
CAN – Cantabrian Sea
NGAL – North Galicia
SGAL – South Galicia
NPOR – North Portugal
SWPOR – Southwest Portugal
SPOR – South Portugal
CAD – Gulf of Cadiz
Results

1. Cohort dispersal between areas

2. Inflow and outflow areas, flow directions

3. Relationship between outflow, cohort strength, density and Chl $a$ in spring and summer
Recent strong cohorts born in BISC did not flow to northern Spain or south of it. 

NPOR≈SWPOR 
CAN≈NGAL 

1. Cohort dispersal

Two-part GAM fitted to survey abundance data 
Age, area and cohort as predictor variables 
Presence model explained 46.5% deviance 
Count model explained 74.8% deviance
**Flow?**

**ONE COHORT**

Typical of Cantabrian Sea

**INFLOW**

Total bars: survey abundance
Red lines: natural + fishing mortality
Grey part of bars: fish that entry the area

**INFLOW: index positive**

Typical of North Portugal

**OUTFLOW**

Black part of bars: survey abundance
Red lines: natural + fishing mortality
Grey part of bars: fish that exit the area

**OUTFLOW: index negative**
Inflow and outflow areas

- **bisc**: BISC~SGAL~SPOR – mostly inflow
- **can**: CAN~NGAL – only inflow
- **npor**: NPOR~SWPOR – mostly outflow
- **cad**: CAD – inflow and outflow
### Relative flow index

<table>
<thead>
<tr>
<th></th>
<th>bisc</th>
<th>can</th>
<th>ngal</th>
<th>sgal</th>
<th>npor</th>
<th>swpor</th>
<th>spor</th>
<th>cad</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age 1-2</td>
<td>32</td>
<td>82</td>
<td>208</td>
<td>114</td>
<td>-75</td>
<td>-25</td>
<td>38</td>
<td>17</td>
</tr>
<tr>
<td>Age 2-3</td>
<td>1</td>
<td>63</td>
<td>177</td>
<td>66</td>
<td>-17</td>
<td>-5</td>
<td>31</td>
<td>-11</td>
</tr>
</tbody>
</table>

**Relative inflow index**
- No. individuals that flow into the area
- No. individuals born locally

**Relative outflow index**
- No. individuals that flow out of the area
- No. individuals stay locally
Flow directions

Individuals flow from North Portugal to all other areas except the Gulf of Cadiz.

Gulf of Cadiz not connected with other areas.

Significant Spearman correlations between relative flow indices at the 0.01 level.
Relationship between outflow, cohort strength, density and Chl a (spring, summer)

Outflow from North Portugal significantly correlated with cohort strength ($r^2=0.26$, $p<0.01$).

Outflow from Southwest unrelated to all tested variables.
Brief summary

• All areas, apart from CAD, appear to be connected to west Portugal by cohort dispersal

• CAN and NGAL depend on dispersal from west Portugal

• SPOR depends on a mixture of local recruitment and inflow from west Portugal

• Flow of sardine from west Portugal to BISC contradicts evidence they are self-sustained populations

• Connectivity influenced by recruitment strength; environmental conditions affecting recruitment will also impact dispersal

• North stock is not contributing to avoid the decrease of the South stock
Final remarks

• Sensitivity of the flow index to various assumptions (survey catchability, natural mortality) needs to be tested

• Combine our approach with otolith microchemistry, growth pattern analysis, IBM

• Integrate regional dynamics and connectivity into assessment and fisheries management
Thank you very much for your attention!
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