The lost generation:

Spring spawning and connectivity in the Georges Bank sea scallop population

Chad Gilbert, W Gentleman, C DiBacco, C Johnson
Scallops on Georges Bank: connected subpopulations

Chile, March 2011

Introduction – Methods – Results – Analysis – Conclusion

3 subpopulations
Planktonic larvae
Recirculate in gyre
Interested in pop. connectivity

ICJ line

GSL
NEP
CF
What We Know About the Fall Spawn

Significant retention, exchange
(Tremblay et al., 1994)

Inter-annual variation in physics matters
(Tian et al., 2009)
Factor of 5

Vertical Distribution matters
(Gilbert et al., 2010)
Factors of 1-5

Gilbert et al. (2010)
But What About Spring?

Scallops also spawn in spring (DiBacco, 1995)

Others ignored spring:
- Lower fecundity
- Lower retention
- Lower survivorship

Gilbert et al. (2010): Significant retention in spring

Objective:
Quantify contribution of spring spawn to population connectivity
Model overview

3D particle-tracking model (Gilbert et al., 2010)
Coupled with an IBM

Introduction – Methods – Results – Conclusion
1. “Settlement Distribution”

Where do larvae begin settlement?

2. “Larval Connectivity Matrix”

\[ \phi(i,j) = \# \text{ from bed } j \text{ settling in bed } i \]

\[
\begin{array}{c}
\phi(GSC,GSC) \\
\phi(GSC,NEP) \\
\phi(GSC,SF) \\
\phi(NEP,GSC) \\
\phi(NEP,NEP) \\
\phi(NEP,SF) \\
\phi(SF,GSC) \\
\phi(SF,NEP) \\
\phi(SF,SF) \\
\phi(UH,GSC) \\
\phi(UH,NEP) \\
\phi(UH,SF)
\end{array}
\]

GSC, NEP, SF spawning beds
UH – unsuitable habitat
Fecundity

DFO – Years 1984-2004 – 3 Size-classes

<table>
<thead>
<tr>
<th>Size</th>
<th>(DiBacco, pers. comm.)</th>
<th>Fec. (eggs x 106)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Spring</td>
</tr>
<tr>
<td>Small (50-95 mm)</td>
<td>21</td>
<td>36</td>
</tr>
<tr>
<td>Medium (95-120 mm)</td>
<td>33</td>
<td>68</td>
</tr>
<tr>
<td>Large (120-170 mm)</td>
<td>61</td>
<td>132</td>
</tr>
</tbody>
</table>

Fecundity is size-specific
Fall matches previous estimates
Spring is ~1/3 of reproductive output
Estimating Abundance & Distribution

DFO & NOAA – Years 1996-2004 – 3 Size-classes

Tow data

Female Abundance

Chile, March 2011

Introduction – Methods – Results – Conclusion
Spawning Field

spawning field = \sum \text{fecundity(size)} \times \text{females(size)}

spatial variation within subpopulations
same distribution in both seasons
spring 1/3 of spawning, fall \sim 2/3

Chile, March 2011
Simulated larval dispersal in fall
Mortality rate: constant, 20% d⁻¹

<table>
<thead>
<tr>
<th>Larvae (1010)</th>
<th>Spawn</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GSC</td>
</tr>
<tr>
<td>Settle</td>
<td></td>
</tr>
<tr>
<td>GSC</td>
<td>-</td>
</tr>
<tr>
<td>NEP</td>
<td>-</td>
</tr>
<tr>
<td>SF</td>
<td>-</td>
</tr>
<tr>
<td>UH</td>
<td>22</td>
</tr>
</tbody>
</table>
Simulated larval dispersal in spring
Mortality rate: constant, 20% d⁻¹

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<th>Spawn</th>
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<tr>
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<td>GSC</td>
</tr>
<tr>
<td>GSC</td>
<td>-</td>
</tr>
<tr>
<td>NEP</td>
<td>-</td>
</tr>
<tr>
<td>SF</td>
<td>^</td>
</tr>
<tr>
<td>UH</td>
<td>1</td>
</tr>
</tbody>
</table>

Long PLD reduces survivorship (1/18)

Spring negligible for const. m.
Re-ran spring simulation

Mortality rate: Q10 = 2

<table>
<thead>
<tr>
<th>Settle</th>
<th>Larvae (1010)</th>
<th>Spawn</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GSC</td>
<td>NEP</td>
</tr>
<tr>
<td>GSC</td>
<td>-</td>
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</tr>
<tr>
<td>NEP</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>SF</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>UH</td>
<td>23</td>
<td>345</td>
</tr>
</tbody>
</table>

Spring connectivity maybe not negligible...
Spring vs Fall

What portion of larval connectivity is from spring?

<table>
<thead>
<tr>
<th>Spring (%)</th>
<th>Spawn</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GSC</td>
<td>NEP</td>
</tr>
<tr>
<td>Settle GSC</td>
<td>45</td>
<td>0</td>
</tr>
<tr>
<td>NEP</td>
<td>19</td>
<td>65</td>
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<tr>
<td>SF</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>UH</td>
<td>36</td>
<td>41</td>
</tr>
</tbody>
</table>

Retained in metapopulation:

- Fall: 5 Trillion
- Spring: 1.4 Trillion

20% of larvae settling in metapopulation are spring-spawned
Summary

1. Reduced fecundity   2. Reduced retention   3. Reduced survivorship

- Spring fecundity estimates are conservative
Summary

1. Reduced fecundity
2. Reduced retention
3. Reduced survivorship

- Spring retention may be underestimated
- Vertical distribution matters, but unknown!
Summary

1. Reduced fecundity  
2. Reduced retention  
3. Reduced survivorship

- Mortality critical, but unknown!

Depends on several factors:

- 1. Predation
- 2. Abiotic
- 3. Food

Spring on GB:

- 1. More zooplankton
- 2. Cool, well-mixed
- 3. More phytoplankton
Conclusion

Formal model forced us to examine assumptions closely

Spring spawn may contribute significantly to population (despite good, but non-quantitative arguments)

Need more study on:
1. Seasonal fecundity
2. Larval depth-distribution in spring
3. Seasonal larval mortality rates

PLEASE?