Bayesian modeling of Atlantic salmon smolt inter-stage survival from Canadian rivers

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The Issue

- North American salmon abundance stuck at historic low levels.
- Hypotheses re. freshwater, estuary, sea.
- High juvenile densities in key rivers.
- Points to an unknown problem in ocean.
- Follow the problem.
Tagging

Sonic tag smolt from rivers in Gulf of St Lawrence, starting:

- 2003 NW & SW Miramichi
- 2004 Restigouche
- 2006 Cascapédia
- More than 2300 smolt tagged
Wire key choke points on migration routes
- Head of tide zones
- Estuary/Bay exits
- Gulf

<table>
<thead>
<tr>
<th>Release location</th>
<th>Release to head of tide (km)</th>
<th>Head of tide to bay array (km)</th>
<th>Bay array to Strait of Belle Isle (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SW Miramichi</td>
<td>127</td>
<td>68</td>
<td>~ 800</td>
</tr>
<tr>
<td>NW Miramichi</td>
<td>31</td>
<td>67</td>
<td>~ 800</td>
</tr>
<tr>
<td>Restigouche</td>
<td>115</td>
<td>106</td>
<td>~ 800</td>
</tr>
<tr>
<td>Cascapedia</td>
<td>8</td>
<td>47</td>
<td>~ 800</td>
</tr>
</tbody>
</table>
Hierarchical Modelling of Inter-Stage Survival Rates

HoT
2003-2014

Outer Bay
2003-2014

SoBI
2007-2014

Cormac-Jolly-Seber *mark and recapture model*

- disentangle the imperfect detection \( (p) \) of tagged smolts on the sonic arrays from apparent survival.
Hierarchical Modelling of Inter-Stage Survival Rates

HoT 2003-2014

Outer Bay 2003-2014

SoBi 2007-2014

Sentinel tags
Hierarchical Modelling Assumptions

Survival and detection probabilities assumed exchangeable & conditional on:

• **HoT arrays (4):** exchangeable among years for each river.

• **Bay arrays (2):** exchangeable among years and rivers which shared a common bay.

• **SoBI array:** probabilities of detection (\(p\)) and survival (\(\phi\)) can only be estimated with a prior assumption for \(p\) at this array.
  
  – prior for \(p\) was derived using sentinel tags placed at three distances near two receivers.
  
  – mean \(p\) from logistic model of detection vs distance was 0.44
• Head of tide (HoT) array: high probability of detection.
• Bay arrays: Miramichi line is more efficient than Chaleur array.
• Strait of Belle Isle (SoBI) array: p distributions dominated by prior.
What have we learned?

• Survival rates in the freshwater are high (80 to 95%).

• Survival rates through the bay are variable.
  - Chaleur Bay: Restigouche: 68%, Cascapédia: 76%.
  - Troublesome results for smolt passing Miramichi Bay.
  - NW survival only 28% last 2 years (2013, 2014).
  - SW survival only 43% last 2 years (2013, 2014).

• Survival through the Gulf of St. Lawrence highly variable.
What’s next?

1. Need a better estimate of survival through Gulf of St. Lawrence.
   - Second Strait of Belle Isle Array
Strait of Belle Isle Arrays

Labrador

Newfoundland

New array deployed in 2015

3.85km

19km

21.25km

19km

Newfoundland
1. Need a better estimate of survival through Gulf of St. Lawrence.
   - Second SoBI array

2. More adjustments needed to get a clear picture of survival estimates.
   - Tag loss
   - Predation Events
Acknowledgements

- Countless volunteers
- *Adopt a Smolt and Kelt* Donors
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