Recruitment strength indices for northern British Columbia stocks of Pacific herring

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British Columbia
Pacific Herring

2008 B.C. Capture Fishing by Value
- Wild Salmon: 7%
- Tuna & Other: 8%
- Herring: 6%
- Wild Shellfish: 36%
- Groundfish: 43%

Landed Value ($millions)

Year
- 1999P
- 2000P
- 2001P
- 2002P
- 2003P
- 2004P
- 2005P
- 2006P
- 2007P
- 2008E

- Food and Bait
- Roe Herring
- Spawn on Kelp
Herring are an important prey species.
British Columbia Pacific Herring

5 major & 2 minor fishing stocks

Map courtesy of Kristen Daniel, DFO
Stock Assessment & Fishery Management

- Catch-Age model using spawn survey data as independent abundance index
- Harvest Control Rule in place since 1986
- 20% fixed harvest rate
- Fishing threshold reference point set at 25% of estimated $B_0$
Pacific Herring Biomass, 1951-2009

DFO 2009
Pacific Herring

• Most recruit to fishery at age 3
• Recruits can represent up to 50% of the population
• Migrate between summer feeding grounds (mixed stocks) and winter spawning grounds
Recruitment forecast rules, Southern stocks

- Independent estimates of recruitment based on offshore survey (Tanasiuchuk 2002).

- Proportion age 2+ fish in offshore summery feeding area indicative of proportion age 3 fish on spawning grounds (i.e., recruits).

Map courtesy of Kristen Daniel, DFO
Recruitment forecast rules, Northern Stocks

• No dedicated survey

• Precautionary Rules:
  1. If pre-fishery biomass < cutoff in previous year, assume POOR recruitment for forecast
  2. If pre-fishery biomass > cutoff in previous year & recruitment good in previous 2 years, assume GOOD recruitment for forecast
  3. If Rule 1 or Rule 2 DO NOT APPLY, assume AVERAGE recruitment for forecast
Summer feeding &
winter spawning
grounds

Map courtesy of Kristen Daniel, DFO
Herring Dispersal Related to Temperature

(Ware and Schweigert 2001 and 2002)

- High fidelity to spawning grounds
- Straying rates = 2-25%
- Summer exchange individuals in feeding areas
- Dispersal rate affected by:
  - temp, SSB, recruits

Map courtesy of Kristen Daniel, DFO
• GOAL: predict recruitment strength to enhance stock assessment and management advice.

• OBJECTIVES:

  1. Examine other survey data for bycatch of herring (groundfish, juvenile salmon, juvenile herring surveys)
  2. Explore potential to provide indices of herring recruitment strength for the three northern stocks.

• HYPOTHESES:

  1. Recruitment to winter fishery related to prop. age 2+ in summer
  2. Recruitment to winter fishery related to summer temperature
Methods

Estimate recruitment strength based on the relationship between:

RESPONSE: recruit fish (prop. age 3 herring) present on spawning grounds (as sampled in herring test fisheries)

PREDICTOR: pre-recruit herring in summer feeding aggregations (prop. age 2+ fish)

PREDICTOR: average summer sea surface temperature in feeding grounds (BC lighthouse)
Methods

• Test for normality (Shapiro-Wilk)
• Test for autocorrelation (Durbin-Watson)
• Least squares linear regression (recruits \sim survey\ prop.\ age\ 2^+)
• Leave-one-out analysis
• Geometric mean regression (recruits \sim survey\ prop.\ age\ 2^+)
• Multiple regression (recruits \sim survey\ prop.\ age\ 2^+\ and\ SST)
Proportion age 2+ herring in offshore summer feeding grounds sampled by groundfish survey, Hecate Strait

Age 2+ herring = 160 - 180 mm
Prop. age 2+ range = 0 - 77%
avg. = 25%
Response: recruit fish (prop. age 3 herring) present on spawning grounds (pre-fishery herring test fisheries)

<table>
<thead>
<tr>
<th>Year (winter fishery)</th>
<th>CC Adults</th>
<th>CC Age 3</th>
<th>PRD Adults</th>
<th>PRD Age 3</th>
<th>HG Adults</th>
<th>HG Age 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985</td>
<td>4,081</td>
<td>1,670</td>
<td>2,869</td>
<td>216</td>
<td>2,653</td>
<td>458</td>
</tr>
<tr>
<td>1988</td>
<td>4,181</td>
<td>2,879</td>
<td>2,981</td>
<td>911</td>
<td>1,676</td>
<td>855</td>
</tr>
<tr>
<td>1990</td>
<td>4,682</td>
<td>278</td>
<td>4,100</td>
<td>737</td>
<td>3,942</td>
<td>389</td>
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<tr>
<td>1992</td>
<td>6,282</td>
<td>3,641</td>
<td>3,340</td>
<td>1,330</td>
<td>2,294</td>
<td>983</td>
</tr>
<tr>
<td>1994</td>
<td>5,472</td>
<td>1,261</td>
<td>5,425</td>
<td>274</td>
<td>1,219</td>
<td>52</td>
</tr>
<tr>
<td>1999</td>
<td>3,884</td>
<td>376</td>
<td>1,720</td>
<td>95</td>
<td>487</td>
<td>13</td>
</tr>
<tr>
<td>2001</td>
<td>3,052</td>
<td>250</td>
<td>2,710</td>
<td>1,064</td>
<td>913</td>
<td>230</td>
</tr>
<tr>
<td>2003</td>
<td>3,454</td>
<td>1,781</td>
<td>2,842</td>
<td>1,705</td>
<td>1,992</td>
<td>1,376</td>
</tr>
<tr>
<td>2006</td>
<td>5,135</td>
<td>639</td>
<td>1,663</td>
<td>283</td>
<td>734</td>
<td>72</td>
</tr>
<tr>
<td>2008</td>
<td>1,572</td>
<td>162</td>
<td>2,072</td>
<td>391</td>
<td>833</td>
<td>60</td>
</tr>
</tbody>
</table>

Prop. age 3 range = 2 - 69% avg. = 26%
Recruits to winter spawning area

Central Coast

Pre-recruits in summer feeding area

R² = 0.494
p = 0.023
Recruits to winter spawning area

Pre-recruits in summer feeding area

Prince Rupert District

prop. age 3 test fishery

prop. age 2+ groundfish survey

R² = 0.463
p = 0.030
Recruits to winter spawning area

Pre-recruits in summer feeding area

Prop. Age 2+ groundfish survey

Prop. Age 3 test fishery

Haida Gwaii

$R^2 = 0.638$

$p = 0.006$
Summer feeding & winter spawning grounds

Map courtesy of Kristen Daniel, DFO
Recruits vs. Summer sea surface temperature
## Multiple Regression

**Recruits ~ prop. age 2+ and summer SST**

<table>
<thead>
<tr>
<th>Stock</th>
<th>$R^2$</th>
<th>p-value Prop. age 2+</th>
<th>p-value Summer SST</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC</td>
<td>0.544</td>
<td>0.053</td>
<td>0.408</td>
</tr>
<tr>
<td>PRD</td>
<td>0.729</td>
<td>0.046 *</td>
<td>0.034 *</td>
</tr>
<tr>
<td>HG</td>
<td>0.829</td>
<td>0.006 *</td>
<td>0.027 *</td>
</tr>
</tbody>
</table>

* significant p<0.05
Conclusions

Hypothesis 1

• Positive relationship between recruitment to winter fishery and prop. age 2+ in summer.

• Groundfish survey samples sufficient to test hypotheses.

• Lack of annual survey precludes annual recruit prediction.

• Relationships suggest significant mixing of stocks in common summer feeding ground.
Summer feeding & winter spawning grounds

Map courtesy of Kristen Daniel, DFO
Conclusions

Hypothesis 2

• Negative relationship between recruitment to PRD and HG winter fisheries and summer temp.

• CC recruitment not related to Hecate St. temp. indicating:
  – no relationship with temp., or
  – more fish using QC Sound feeding area (not examined here).

Note: Stocker et al. (1985) dome-shaped relationship between SOG recruits/spawner and temp.
Implications

• Collaboration, coordination across programs:
  – Summer offshore groundfish survey - herring age structure provides predictor of recruitment strength to northern stocks.

• Progress towards increased understanding of climate effects on marine ecosystems:
  – Summer SST improves the prediction (2 of 3 stocks),
  – Temperature changes may affect recruitment strength via dispersal rates between areas.

• Other factors
  – Food availability and/or quality
  – Predator abundance (e.g., cod (Walters et al. 1986))
  – Competitor abundance (e.g., sardine)
  – Larval transport (Ramey and Wickett 1973)
Future Work

- Explore possibility of including recruit forecast in stock assessment.
- Continue using groundfish survey data; explore data in QCS.
- Continue collection of herring recruit data on other surveys (juvenile salmon and herring surveys).
- Explore possibility of dedicated annual herring recruit survey.
- Further explore inclusion of environmental/biological components.
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