Estimation of the Intrinsic Rate of Increase for Georges Bank Yellowtail Flounder

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This document is available on the Internet at:
Introduction

• Estimate reproductive potential of GB yellowtail flounder using life-table analysis.

• Methodology based on the Euler-Lotka equation (Caswell 1989)

• Apply recently derived GB YT fecundity relationship that includes condition (WP 33)

• Analysis provides:
  • Intrinsic rate of increase $\rightarrow r$ and instantaneous growth rate $\lambda = \exp (r)$
  • Net Reproductive rate / reproductive potential $\rightarrow$ Ro
Input Data:

• Time series: 1973-2013

• Population number at age (N); (2013 VPA, Legault 2013)

• Recruitment (R) = age 1 N

• Sex ratio (X); assume 50/50

• Maturity at age (M); times series average (2013 VPA, Legault 2013)

• Mean length at age = $L_a$
  • Use NEFSC spring research bottom trawl survey: Closest to spawning time
  • Missing mean length for age 1 for most years, used a 10 year mean for missing years
  • Some missing age 6 or 7, use average of adjacent years
  • Regression fit to observed mean length, fitted mean length applied in life-table
Input Data:

• Condition
  • Individual weight only available since 1992.
  • Fulton’s Condition at length \( l \) = \( K_l = \left[ \frac{Wt (g)}{Length (mm)^3} \right] \times 100000 \)
  • \( K \) assumed = 1 for earlier years
  • Mean \( K \) at age = \( K_a = \frac{\sum K_l}{n} \)

• Potential Annual Fecundity (F) : combined 2010-2013 (WP 33 McElroy)
  • \( \ln (PAF)_a = \beta_0 + \beta_1 \ln L_a (mm) + \beta_2 \text{Oocyte diam} + \beta_3 K_a \)
  • oocyte diameter = 450 um (near spawning size)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-3.3816805</td>
<td>2.7745847</td>
</tr>
<tr>
<td>LN (TL)</td>
<td>2.6875112</td>
<td>0.4542765</td>
</tr>
<tr>
<td>Mean Oocyte Diameter</td>
<td>-0.0023884</td>
<td>0.0005946</td>
</tr>
<tr>
<td>( K )</td>
<td>2.8512876</td>
<td>0.2466295</td>
</tr>
</tbody>
</table>

• Total Egg production at age = \( TEP_a = N_a \times X_a \times M_a \times F_a \)

• Recruitment survival = \( S = \frac{R_{y-1}}{TEP_y} \)
• Average Rct Z = \( \frac{\sum -\ln \left[ \frac{R}{TEP_y} \right]}{n} \)

• Maximum age ~ 11
Population Numbers at ages 1-6+ from 1973-2013

Georges Bank Yellowtail Flounder
GB YT NEFSC Spring - Observed Mean Length

Spring Observed Mean length at age 1973-2013
Spring
Fitted mean length at age 1973-2013

Ages 7+ low sample size
Fulton’s Condition

Fulton's K (Spring survey - females only)
Life-Table Analysis

Euler-Lotka equation; solve to estimate $r$, intrinsic rate of increase

$$\sum_{x=\alpha}^{x=\beta} e^{-rx} l(x) m(x) = 1$$

where

- $l(x)$ = the probability of surviving to age $x$
- $m(x)$ = number of female offspring produced at age $x$
- $\alpha$ = age 0
- $\beta$ = maximum age

Derive annual instantaneous growth rate:
- $\lambda = \exp (r)$
Life-Table Analysis

Derive Net reproductive rate:

\[ R_o = \sum_{x=\alpha}^{x=\beta} l(x) \cdot m(x) \]

where

- \( l(x) \) = the probability of surviving to age \( x \)
- \( m(x) \) = number of female offspring produced at age \( x \)
- \( \alpha \) = age at maturity
- \( \beta \) = age at death
annual instantaneous growth rate: $\lambda = \exp(r)$
Results – influence of K on r

K has strong effect on trend in r

K = 1 in fecundity eqn from 1973-1991
K = observed condition from 1992→

K = 1 in all years
Results – influence of K on Ro

K has strong effect on trend in Ro

K = 1 in fecundity eqn from 1973-1991
K = observed condition from 1992

K = 1 in all years
Summary

• Population growth ($\lambda$) and net reproduction (Ro) have been declining since 1998

• Estimation of $r$ and Ro influenced strongly by inclusion of condition in fecundity estimation

• If condition is not included, would mistakenly conclude stock is relatively stable even though population numbers are declining.

Further work:

• Sensitivities to varied sex ratio, since YT have dimorphic growth; Females grow/survive to larger size than males

• Sensitivity and Elasticity (proportional effect) to measure how changes in vital rates i.e. juvenile mortality, survival at age, effect estimation of $\lambda$

• Projections of Spawning Stock Biomass (Monte Carlo Analysis)
Literature Cited


