Effects of Survey Uncertainty on Risk of Violating Escapement and F/M Thresholds for Illex Squid: 1997-2021

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Presentation to MAFMC Scientific and Statistical Committee
Webinar Meeting
March 7, 2023
Overview

• Review previous methods for estimating escapement and probability of falling below candidate thresholds

• Method for considering additional uncertainty of survey biomass estimates for period 1997-2021

• Compute effects of additional uncertainty
  • Side by side comparison for Biomass, F, Escapement and F/M
  • Side by side probabilities of violating escapement and F/M ratios for estimates with and without survey uncertainty
  • Probabilities that potential quotas from 24,000 to 60,000 mt violate candidate thresholds.
Review of Model Theory

• Input data
  • Time series of catch \(C_t\), fall survey index \(I_{F,t}\), coefficient of uncertainty in fall survey \(CV_t\)

• Parameters
  • Catchability (q), Availability (v), Natural Mortality (M),

• Simulation Controls
  • Upper and Lower bounds for q, v, M and \(I_{F,t}\) via selection of confidence interval \(\alpha\).
  • Number of intervals for each parameters
  • Candidate thresholds for Escapement and F/M

• Number and magnitude of alternative quotas to be evaluated
Finding F

1. Expand Fall survey index to total assuming q and v

\[ B_t = \frac{I_t A}{q a v} = \frac{A l_t}{q a v} \]

2. Write \( B_t \) as function of \( B.0 \) and \( Z \)

\[ B_t = B_0 \ e^{-Z \ t} \]

3. Baranov catch equation assuming \( M \)

\[ B_0 = \frac{C_t}{F + M(1 - e^{-(F+M)})} \]

4. Combine Eq. 2 and 3

\[ B_t \ e^{(F+M)} = \frac{C_t}{F + M(1 - e^{-(F+M)})} \]

5. Plug Eq. 1 into Eq. 4

\[ \frac{A l_t}{q a v} \ e^{(F+M)} = \frac{C_t}{F + M(1 - e^{-(F+M)})} \]

6. Solve for \( F \) given assumed levels of \( q, v, M \) and observations of \( I_t \) and \( C_t \) in Eq. 5
**Escapement Estimation for OBSERVED Catches**

- Find B.0 and F for each year given C(t), I(t) and assumed q,v,M.
- Project terminal population without fishery
- Compute escapement as ratio of observed B(t) over B(t|F=0)
- Or equivalently
- This formulation is useful for evaluating alternative quotas

\[
B_{t, \text{without fishery}} = B_0 e^{-Mt}
\]

\[
\text{Escapement} = \frac{B_t}{B_{t, \text{without fishery}}}
\]

\[
\text{Escapement} = \frac{B_t}{B_{t, \text{without fishery}}} = \frac{B_0 e^{-(F+M)}}{B_0 e^{-M}} = e^{-F}
\]
Escapement Estimation for ALTERNATIVE Catches

- Find B.0 and F for each year given observed C(t), I.f(t) and assumed q,v,M.
- Assume alternative catch C_H
- Find F_H associated with alternative catch C_H
- Compute escapement as ratio of observed B(t) over B(t|F=0)

\[ B_0 = \frac{C_H}{F_H} \left( \frac{F_H}{F_H + M} (1 - e^{-(F_H+M)}) \right) \]

\[ \text{Escapement}(B_0, C_H) = \frac{B'_t}{B_{t,\text{without fishery}}} = \frac{B_0 e^{-(F_H+M)}}{B_0 e^{-M}} = e^{-F_H} \]
Revised methodology includes all of the above steps PLUS uncertainty in the survey derived estimates of minimum biomass.
### Parameterization of model

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range =Max/Min</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catchability</td>
<td>4X</td>
<td>Uniform (min, max)</td>
</tr>
<tr>
<td>Availability</td>
<td>2X</td>
<td>Uniform (min, max)</td>
</tr>
<tr>
<td>Natural Mortality</td>
<td>13X</td>
<td>Uniform (min, max)</td>
</tr>
<tr>
<td>Survey Estimate ($\alpha=0.1$)</td>
<td>Ave~2X</td>
<td>Normal(mean, SE</td>
</tr>
<tr>
<td>(Z_\alpha=1.28)</td>
<td>Range 1.2-14X over years</td>
<td></td>
</tr>
</tbody>
</table>

\[
N.q \times N.v \times N.M \times N.I = N.sim
\]

25 * 20 * 20 * 25 = 250,000 evaluations for each year (23) times 37 alternative quotas

\[
\text{Ave} \sim 2X \quad \text{Range} \ 1.2 - 14X \text{ over years}
\]
Stochastic Escapement Model: Turning 69 numbers into 212,750,000 estimates

**Alternative Quotas** = {24,000, 25,000, 26,000,... 58,000, 59,000, 60,000 mt}
Integrating over ranges of uncertainty in $q$, $v$, $M$, $l_{F,t}$
Results

• See Tables 2-8 in report

• General Format of Tables
  • Estimates from Last year using original methods
  • Estimates for same data, using revised method
  • Percentage difference for each parameter
  • Average value over columns

• Tables 2, 3, 4, 5 = Estimates of percentiles of Biomass, F, Escapement, F/M, respectively for each year

• Tables 6, 7, 8 = Probabilities of violating Escapement Thresholds, F/M thresholds and Joint escapement & F/M thresholds for each quota.
Effects on Initial Biomass (B.0) and total Season Fishing Mortality Percentiles for 1997-2021
Effects on Escapement and F/M ratio by percentile for 1997-2021
Figure 3. Empirical relationship between the percent difference in the confidence interval width of initial biomass (B.0) vs the Coefficient of Variation of fall bottom trawl survey.

\[ y = 0.0034x^2 - 0.0545x + 5.0163 \]

\[ R^2 = 0.9991 \]

The y-axis is the percentage change in the ratio of the 90% confidence interval width when the Survey CV is included over the 90% CI width when the Survey CV is NOT included.

Each point represents a given year.

The polynomial fit is purely empirical. Deviations are based on the magnitude of the catch and the fall survey biomass.
Figure 4. Empirical relationship between the percent difference in the confidence interval width of Escapement (Esc) vs the Coefficient of Variation of fall bottom trawl survey.

The y-axis is the percentage change in the ratio of the 90% confidence interval width when the Survey CV is included over the 90% CI width when the Survey CV is NOT included.

Each point represents a given year.

The polynomial fit is purely empirical. Deviations are based on the magnitude of the catch and the fall survey biomass.

\[ y = 0.0007x^3 - 0.0394x^2 + 0.719x \]

\[ R^2 = 0.9908 \]
Effects Survey Uncertainty on Risk of Overfishing for 40,000 mt Quota on Escapement

• In March and July, 2022 the SSC recommended an ABC of 40,000 mt for 2023. The probability of falling below Escapement thresholds (Table 6) were:

<table>
<thead>
<tr>
<th>Escapement Threshold</th>
<th>0.35</th>
<th>0.40</th>
<th>0.5</th>
<th>0.6</th>
<th>0.75</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probability</td>
<td>0.0384</td>
<td>0.0657</td>
<td>0.1519</td>
<td>0.2802</td>
<td>0.5575</td>
</tr>
</tbody>
</table>

The inclusion of uncertainty in survey biomass increased these probabilities to:

<table>
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<th>0.5</th>
<th>0.6</th>
<th>0.75</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probability</td>
<td>0.0437</td>
<td>0.0731</td>
<td>0.1620</td>
<td>0.2912</td>
<td>0.5641</td>
</tr>
</tbody>
</table>

The ratio of these probabilities is

<table>
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<th>0.75</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probability</td>
<td>1.1392</td>
<td>1.1130</td>
<td>1.066</td>
<td>1.0392</td>
<td>1.0118</td>
</tr>
</tbody>
</table>
Conclusions

• Effects of adding uncertainty in survey biomass is relatively minor and does not significantly affect the basis for quota decisions made in 2022.

• WHY?
  • Range of variation considered is relatively small compared to ranges for other parameters, especially M.
  • CVs are relatively low except in a few years.
  • Effect show up in the tails of the Escapement and F/M distributions. The dispersion of the sampling distributions increases. Medians relatively unaffected.
  • Index Uncertainty is normally distributed and symmetric, implies equal # of increases and decreases
  • Less probability mass in the tails relative to uniform distribution