Forage Fish Harvest Control Rules from a Seabird Perspective

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Timothy E. Essington, Margaret Siple, and Andre Punt
Forage Fish and Ecosystem-Based Fisheries Management

Seabirds $\times 10^6$

Anchoveta ($\times$ 500,000 metric tons)

Sardines ($\times$ 10$^3$ metric tons)

Chavez et al. 2003 Science
Call for more conservative harvest control rules
Conservative Forage Fish Control Rules Especially for Seabird Conservation?

1. Diet on Forage Fish

- >90% ~30%
- ~45%

Values from Koehn et al. 2016

2. Central-Place Foraging

3. Link to prey availability "1/3 for the birds" Cury et al. 2011

Boersma et al. 2015 Biological Conservation

Seabird Breeding Success

Prey Abundance
How well do these harvest control rules perform for seabirds?

Protective fishing rules led to less decline for predators

LIMITATIONS

• Limited harvest control rules tests
• Only based on biomass (EwE models)
• No spatial representation
• Aggregate broad “seabird” functional groups

Pikitch et al. 2012
Lenfest Forage Fish Task Force
QUESTIONS
With continued harvest, which forage fish harvest control rule(s) optimize seabird conservation?
➢ How does this vary across seabird life histories?
Forage Fish – Seabird Management Strategy Evaluation-like Simulation Analysis
Answer may vary across seabird species/types
# Seabird Life History

<table>
<thead>
<tr>
<th>Diet Dependence</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foraging Distance</td>
<td>Near</td>
<td>Far</td>
</tr>
<tr>
<td>Diving Type (Foraging Strategy)</td>
<td>Shallow</td>
<td>All depths</td>
</tr>
</tbody>
</table>

- **Biomass thresholds?**
- **MPA?**
- **Temporal closures?**
Harvest Control Rules

- Constant fishing
- Biomass threshold / cut-off rules
- Spatial closures (no fishing, 50% constant F)
- Temporal closures (breeding season)
- Move-on rules
- Top-down indicator

![Diagram showing thresholds for fishing rate and observed biomass vs seabird recruitment.](image-url)
Forage Fish Model Overview and Modifications

Human activities (fishing)

Simulate realistic population dynamics

Implement HCRs

Assessment process

Management decisions (Harvest control rules)

*Once per year – management decision only changes on a yearly basis

*Split up time steps to reflect seabird breeding life history

Slide from Megsie Siple
Toy example – Penguin Case Study

Based on information on Magellanic Penguins in Argentina and work Dr. P. Dee Boersma

Breeding
Ages 4-30

Non-breeding: 6months- Age 3

Stochastic survival

0 to 6 months

50% of diet

Yearly Cycle

Eggs
Non-breeding
Young Chicks
Older Chicks

Photos from P. Dee Boersma and Laura Koehn
Seabird reproduction and survival are dependent on prey availability

Similar curves for:
- Egg survival
- Young chick survival
- Juvenile survival
Prey availability near the colony is most important when chicks are young.

From Boersma and Rebstock 2009 *MEPS*:

Prey availability cut-off at which offspring survival decreases is higher for young chicks.
Proportion of prey near colony varies from year to year.
Test Harvest control rules (based on forage fish model)

- **Constant F**
  - Observed biomass
  - Fishing rate: 0.6

- **“Conservative 1”**
  - Observed biomass
  - Fishing rate: 0.5M
  - Change in catch ≤ 15%
  - 0.6

- **“Conservative 2”**
  - Observed biomass
  - B₀
  - Fishing rate: 0.5F_{MSY}
  - 0.5M

- **“Stability-favoring”**
  - Observed biomass
  - B_{MSY}
  - + change in catch ≤ 15%
  - 0.6
Preliminary Results

Consistent with previous analyses to test impacts of forage fish control rules on seabirds
Preliminary Results Across 100 Simulations

Some overlap between conservative control rules and constant fishing but only one anchovy scenario

NEED MORE SCENARIOS!!!!
But...not all great for catch...

<table>
<thead>
<tr>
<th>Harvest Control Rule</th>
<th>Years with 0 Catch</th>
<th>Long-term Mean Catch (Mil. Metric Tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stability-Favoring</td>
<td>0</td>
<td>3.160186</td>
</tr>
<tr>
<td>Constant F (0.6)</td>
<td>0</td>
<td>3.13537</td>
</tr>
<tr>
<td>Conservative 1</td>
<td>23</td>
<td>2.166532</td>
</tr>
<tr>
<td>Conservative 2</td>
<td>2</td>
<td>2.494449</td>
</tr>
</tbody>
</table>

Need to test the additional harvest control rules that may equally benefit seabird conservation but have some increased benefits for fisheries
Next Steps – test everything!

• Full simulation models for four seabird life history types
• Additional harvest control rules
• Variation in functional responses
• Variation in forage fish parameters
• Suggestions???
Thank you!

• UW School of Aquatic and Fishery Sciences
• Essington Lab
• PICES for travel funding
Questions?