A Bioeconomic Model of the Recreational Gulf of Maine Cod and Haddock Fishery

Min-Yang Lee¹, Scott Steinback¹, and Kristy Wallmo²

¹NOAA Fisheries, Northeast Fisheries Science Center, Woods Hole, MA
²NOAA Fisheries, Office of Science and Technology, Silver Spring, MD
Policy/Research Questions

• How will changes in management measures alter angler fishing effort, angler welfare, recreational fishing mortality, and stock levels of Atlantic cod and haddock in the Gulf of Maine?

• What combination of management measures can achieve conservation objectives?
Outline

• Economic sub-model
• Biological sub-model
• Coupled model
• Simulation process
Model Overview

**Economic Sub-Model**
Estimate a behavioral model for recreational anglers

**“Biological” Sub-Model**
- Expected and actual encounters of fish on a trip
- Fish kept and released are a function of length structure, selectivity, regulations

Simulate angler behavior under alternative stock structures and regulations

**Aggregate and project stocks of fish**

- Effort
- Discards
- Retained
- Welfare

NOAA FISHERIES
Economic Sub Model

- Stated Preference Choice Experiment Survey

- Add-on to NMFS’ MRFSS Survey in 2009 (ME-NJ)

- Voluntary mail follow-up

- Dillman surveying approach
Groundfish Choice Experiment Survey

Five Components

• Description of study
• A species information page
• Screener questions – familiarity and avidity
• CE questions
• Demographic questions
**SECTION B: SALTWATER FISHING TRIPS**

Please compare Trip A, Trip B, and Trip C in the table below, then answer questions 1 and 2. Compare only the trips on this page. Do not compare these trips to trips on other pages in this survey. Assume that the trips below are identical in every way except for the features listed in the table. All regulations remain as they are today unless otherwise noted in the table below.

<table>
<thead>
<tr>
<th>TRIP FEATURES</th>
<th>TRIP A</th>
<th>TRIP B</th>
<th>TRIP C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DAILY BAG (TAKE) LIMIT</strong></td>
<td>4 Pollock</td>
<td>10 Cod</td>
<td>Do something other than saltwater fishing.</td>
</tr>
<tr>
<td>Number of fish you can legally keep per day.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>MINIMUM SIZE LIMIT</strong></td>
<td>23 inch Pollock</td>
<td>22 inch Cod</td>
<td></td>
</tr>
<tr>
<td>Smallest fish you can legally keep of this species.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>NUMBER OF LEGAL-LENGTH FISH YOU CATCH</strong></td>
<td>10 Pollock</td>
<td>1 Cod</td>
<td></td>
</tr>
<tr>
<td>These fish are at least legal minimum size. Some fish are released if you catch more than the daily bag limit.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>NUMBER OF UNDERSIZED FISH YOU CATCH</strong></td>
<td>1 Pollock</td>
<td>3 Cod</td>
<td></td>
</tr>
<tr>
<td>These fish are below the legal minimum size. All of these fish must be released.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>NUMBER OF OTHER FISH YOU KEEP</strong></td>
<td>3 Cod</td>
<td>1 Haddock</td>
<td></td>
</tr>
<tr>
<td>Other fish you catch on this trip that can be legally kept.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TRIP LENGTH</strong></td>
<td>8 Hours</td>
<td>12 Hours</td>
<td></td>
</tr>
<tr>
<td>Total time purchased for this trip.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL TRIP COST</strong></td>
<td>$312</td>
<td>$276</td>
<td></td>
</tr>
<tr>
<td>YOUR share of the fishing trip cost, including bait, ice, fishing equipment, daily license fees, boat rental fees, boat fuel, and round trip transportation costs associated with traveling to and from the fishing location. Travel costs may include vehicle fuel, car rental, tolls, airfare, and parking. This cost does not include the price of food or drink.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. I like this trip best: (Please mark the ONE option YOU like best with a ☑ or ☒)
   - TRIP A ☐
   - TRIP B ☐
   - TRIP C ☐

2. Please rate the trips listed in the table above. (Circle the number that reflects your opinion best.)

<table>
<thead>
<tr>
<th>TRIP A</th>
<th>TRIP B</th>
<th>TRIP C</th>
</tr>
</thead>
<tbody>
<tr>
<td>DISLIKE</td>
<td>1 2 3 4 5 6 7 8 9 10 LIKE</td>
<td></td>
</tr>
<tr>
<td>DISLIKE</td>
<td>1 2 3 4 5 6 7 8 9 10 LIKE</td>
<td></td>
</tr>
<tr>
<td>DISLIKE</td>
<td>1 2 3 4 5 6 7 8 9 10 LIKE</td>
<td></td>
</tr>
</tbody>
</table>
### Attributes and Levels in CE

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bag limits</td>
<td>2, 4, 8, 10</td>
</tr>
<tr>
<td>Size limits:</td>
<td></td>
</tr>
<tr>
<td>Cod</td>
<td>18”, 20”, 22”, 23”, 24”, 26”</td>
</tr>
<tr>
<td>Haddock</td>
<td>12”, 16”, 17”, 19”, 21”, 22”</td>
</tr>
<tr>
<td>Pollock</td>
<td>17”, 19”, 20”, 21”, 23”, 26”</td>
</tr>
<tr>
<td>Number of legal sized fish</td>
<td>1, 3, 6, 10</td>
</tr>
<tr>
<td>Number of undersized fish</td>
<td>1, 3, 6</td>
</tr>
<tr>
<td>Number of other fish</td>
<td>1, 3, 6, 10</td>
</tr>
<tr>
<td>Trip length (hours)</td>
<td>2, 4, 6, 8, 10, 12</td>
</tr>
<tr>
<td>Shore mode trip cost ($/trip)</td>
<td>$15, $35, $60, $90, $120, $150</td>
</tr>
<tr>
<td>All other modes trip cost:</td>
<td></td>
</tr>
<tr>
<td>Hourly trip cost ($/hr.)</td>
<td>$15, $35, $60, $90</td>
</tr>
<tr>
<td>Total trip cost ($/trip=$/hr. x # hrs.)</td>
<td>$30-$1080</td>
</tr>
</tbody>
</table>

**Many Possible Combinations**

**Experimental design literature (Kuhfeld)**

- 26 Unique Surveys
- D-efficiency Score ~73
# Response Rates by State and Residency

<table>
<thead>
<tr>
<th>Intercept State</th>
<th>Mailed</th>
<th>Resident Completed</th>
<th>Non-resident Completed</th>
<th>Total Completed</th>
<th>Completion Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maine</td>
<td>265</td>
<td>67</td>
<td>58</td>
<td>125</td>
<td>47%</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>1238</td>
<td>272</td>
<td>168</td>
<td>440</td>
<td>36%</td>
</tr>
<tr>
<td>New Hampshire</td>
<td>536</td>
<td>124</td>
<td>66</td>
<td>190</td>
<td>35%</td>
</tr>
<tr>
<td>New Jersey</td>
<td>1421</td>
<td>310</td>
<td>124</td>
<td>434</td>
<td>31%</td>
</tr>
<tr>
<td>New York</td>
<td>725</td>
<td>157</td>
<td>7</td>
<td>164</td>
<td>23%</td>
</tr>
<tr>
<td>Connecticut</td>
<td>34</td>
<td>10</td>
<td>3</td>
<td>13</td>
<td>38%</td>
</tr>
<tr>
<td>Rhode Island</td>
<td>358</td>
<td>48</td>
<td>77</td>
<td>125</td>
<td>35%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>4,577</td>
<td>988</td>
<td>503</td>
<td>1,491</td>
<td>33%</td>
</tr>
</tbody>
</table>
Behavioral Model

\[ U_{jn} = \beta_1 \sqrt{E[\text{cod landed}])_{jn}} \]
\[ + \beta_2 \sqrt{E[\text{cod discard}]_{jn}} \]
\[ + \beta_3 \sqrt{E[\text{haddock landed}]_{jn}} \]
\[ + \beta_4 \sqrt{E[\text{haddock discard}]_{jn}} \]
\[ + \beta_5 (\text{Trip length}_{jn} \times \text{boat}_{n}) \]
\[ + \beta_6 [(\text{Trip length})_{jn} \times \text{boat}_{n}]^2 \]
\[ + \beta_7 (\text{optout})_{jn} + \beta_8 (\text{trip cost})_{jn} + \epsilon_{jn} \]

\[ \text{mwtp}_{\text{#cod kept}} = \frac{\beta_1 \left( \frac{1}{2} (\text{#cod kept})^{-\frac{1}{2}} \right)}{\beta_8} \]

Economic Sub-Model
## Behavioral Model Parameters

| Parameter                        | Estimate | Standard Error | t value | Pr > |t| |
|---------------------------------|----------|----------------|---------|------|---|
| √cod kept                       | 0.3243   | 0.0342         | 9.48    | <0.0001 |
| √cod released                   | 0.0943   | 0.0232         | 4.06    | <0.0001 |
| √haddock kept                   | 0.3195   | 0.0317         | 10.08   | <0.0001 |
| √haddock released               | 0.1063   | 0.0274         | 3.88    | 0.0001  |
| Trip length x For-hire          | 0.0743   | 0.0288         | 2.58    | 0.0100  |
| (Trip length)² x For-hire       | -0.003240| 0.002035       | -1.59   | 0.1114  |
| Trip cost                       | -0.005392| 0.000209       | -25.84  | <0.0001 |
| Opt-out                         | -0.2742  | 0.1336         | -2.05   | 0.0401  |
| Likelihood Ratio                | 1,750.1  |                |         |       |
| No. Obs.                        | 4,308    |                |         |       |
| No. Cases                       | 14,233   |                |         |       |
Behavioral Model Summary

- Model estimates how changes in expectations (mainly catch expectations) affects the value of a fishing trip.

But what changes expectations about kept and released fish?
- Regulations, stock structure, other factors.
Behavioral Model Limitations

• No explicit link between changes in regulations and expected catch in behavioral model

• No consideration of stock structures

• Results are not explicitly linked to changes in numbers of trips per season (i.e., effort shifts)
Model Overview

**Economic Sub-Model**
- Estimate a behavioral model for recreational anglers

**“Biological” Sub-Model**
- Expected and actual encounters of fish on a trip
- Fish kept and released are a function of length structure, selectivity, regulations

Simulate Angler behavior under alternative stock structures and regulations

- Effort
- Discards
- Retained
- Welfare
- Aggregate and Project stocks of fish
In the “Biological” Sub-Model:

• Generate expectations about catch:
  • Encounters-per-trip
  • Length of encounters-per-trip
    • Length structure of fish in the ocean
    • Size selectivity of anglers
Encounters-Per-Trip

- The distribution of encounters-per-trip derived from MRIP (2012)
  - Encounters=Kept+ Discard
  - Trips that targeted or caught GOM cod or haddock
- Lots of zeros
  - Approx 25% of trips do not encounter a cod
  - Nearly 60% of trips do not encounter a haddock
Length Distribution of Encounters

- What is the length-distribution of fish encountered by recreational anglers?

- Not the same as:
  - Length distribution of stock
  - Length distribution of historical catch

Pair with bag, size limits to determine how many fish are kept and released.

Doesn’t account for targeting behavior

Doesn’t account for changing stock conditions
Combining Stock Assessment and Recreational Catch data

\[
\begin{align*}
\text{Last Year's (2012) Numbers at Age (Assessments)} & \quad + & \quad 2012 \text{ Age-Length Data (Bottom Trawl Survey)} \\
\text{2012 Catch-at-Length (MRIP)} & \quad / & \quad 2012 \text{ Numbers at Length} \\
\end{align*}
\]

\[
2014 \text{ Projected Numbers at Age} = 2012 \text{ Recreational Selectivity-at-Length} [q]
\]

\[
\begin{align*}
\text{Calculate 2014 Projected Numbers-at-Length} & \quad \times & \quad 2014 \text{ Recreational Selectivity-at-Length} [q] \\
\text{2014 Projected Recreational CPUE-at-Length} & \\
\end{align*}
\]
Recreational Selectivity and Catch-at-length
Model Overview

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Expected and actual encounters of fish on a trip
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Simulate Angler behavior under alternative stock structures and regulations

Effort
Discards
Retained
Welfare
Aggregate and Project stocks of fish

“Biological” Sub-Model
Simulating *Expected Catch* for a Trip

1. Draw “Encounter” limit
2. Draw Length of A Fish
3. Greater Than Minimum Size?
   - Yes: Add to Kept
   - No: Add to Release
4. Reached “Encounter” Limit?
   - Yes: Stop Fishing
   - No: Repeatedly go back to 1.
5. Reached Possession Limit?
   - Yes: Stop Fishing
   - No: Repeatedly go back to 1.

- Compute Expected Catch (numbers of fish)
Trip Participation

- Expected Catch
- RUM: Probability a Prospective Trip Will Occur
  - Trip Does not Occur
  - Trip Occurs
    - WTP For a Trip
      - Rum Model Coefficients

Other Trip Characteristics (costs, mode, length of trip)
**Trip Participation (Updated)**

- **Expected Catch on Trip**
- **RUM: Probability a Prospective Trip Will Occur**
- **WTP For Trip**
- **Rum Model Coefficients**

- **Other Trip Characteristics** (costs, mode, length of trip)

**Aggregate WTP**

\[
\text{Aggregate WTP} = \sum_{i=1}^{N} \text{Prob}_i \times WTP_i
\]
Expected Catch  ➔  Actual Catch

\[ \text{Aggregate Expected Catch} = \sum_{i=1}^{N} \text{Prob}_i \times \text{Expected Catch}_i \]

- Aggregate Expected Catch > Aggregate Actual Catch
Simulating **Actual Catch**

1. **Draw a “Encounter” limit**
2. **Draw Length of A Fish**
   - **Greater Than Minimum Size?**
     - Yes: **Add to Bag**
     - No: **Discard**
   - No: **Reached “Encounter” Limit?**
     - Yes: **Reached Possession Limit?**
       - Yes: **Stop Fishing**
       - No: **No**
     - No: **Stop Fishing**
3. **Compute Actual Catch (numbers of fish)**
Aggregate Catch

\[ Aggregate \text{Catch} = \sum_{i=1}^{N} \text{Prob}_i \times \text{SimulatedActualCatch}_i \]
Weights of Kept and Released Fish

• Compute weights of kept and released fish on each simulated trip from length-weight equations used in the assessments
Simulating Over Entire Fishing Year

- The algorithm simulates trips until the maximum number of choice occasions (potential trips) is reached
- Potential Trips?
  - Set a number for potential trips that is large enough so that it is not binding if the fishery becomes more desirable, but is not unrealistic
Calibration

- Use possession and size limits in effect for 2013.
- Adjust number of “potential trips” until $\sum_{i=1}^{N} Prob_i = \text{MRIP actual trips}.$

<table>
<thead>
<tr>
<th></th>
<th>MRIP FY2013</th>
<th>Model Predictions FY2013</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential Trips (N)</td>
<td>N/A</td>
<td>410,000</td>
<td></td>
</tr>
<tr>
<td>Trips</td>
<td>212,578</td>
<td>212,409</td>
<td>4.6%</td>
</tr>
<tr>
<td>Cod Landings (lbs)</td>
<td>1,226,862</td>
<td>1,284,387</td>
<td>4.7%</td>
</tr>
<tr>
<td>Cod Discard Mortality (lbs)</td>
<td>225,251</td>
<td>186,484</td>
<td>-17.2%</td>
</tr>
<tr>
<td>Total Cod Mortality (lbs)</td>
<td>1,452,113</td>
<td>1,470,871</td>
<td>1.3%</td>
</tr>
<tr>
<td>Had Landings (lbs)</td>
<td>529,011</td>
<td>493,214</td>
<td>-6.8%</td>
</tr>
<tr>
<td>Had Discard Mortality (lbs)</td>
<td>455,149</td>
<td>466,313</td>
<td>2.5%</td>
</tr>
<tr>
<td>Total Had Mortality (lbs)</td>
<td>984,160</td>
<td>959,526</td>
<td>-2.5%</td>
</tr>
</tbody>
</table>
## FY2014 Simulation Results

<table>
<thead>
<tr>
<th></th>
<th>Trips (Median)</th>
<th>% Under Cod ACL (100 trials)</th>
<th>% Under Haddock ACL (100 trials)</th>
<th>Cod Mortality lbs (Median)</th>
<th>Haddock Mortality lbs (Median)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SQ FY2013 in FY2014</td>
<td>252,405</td>
<td>0</td>
<td>16</td>
<td>2,042,100</td>
<td>585,100</td>
</tr>
<tr>
<td>FY2014 Measures</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(cod: min 19” to 21””, wave 5 closed)</td>
<td>127,600</td>
<td>78</td>
<td>52</td>
<td>929,162</td>
<td>177,749</td>
</tr>
<tr>
<td>(had: 3 fish bag, wave 2 and 5 closed)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FY2014 Measures</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(updated haddock assessment)</td>
<td>151,200</td>
<td>89</td>
<td>0</td>
<td>877,104</td>
<td>554,538</td>
</tr>
<tr>
<td>(haddock discard mortality rate change from 0 to 50%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GOM Cod</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FY2014 ACL (lbs)</td>
<td>1,071,436</td>
<td>191,800</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FY2014 ACL (lbs)</td>
<td>1,071,436</td>
<td>381,396</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Updated Haddock Assessment)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Important Assumptions

• No heterogeneity in catch rates across fishing modes

• Anglers stop fishing for either species when they hit the “assigned encounter limit” or the bag limit

• Noncompliance (size and bag limits)
  • Size limit noncompliance incorporated
  • Assume compliance with bag limits
  • No recreational high-grading
Extensions

- Retention of more fish than possession limit

- Medium term projections:
  - Given a discard mortality assumption, we can compute projected numbers-at-age of harvested cod and haddock
  - Project stocks/biomass a few years into the future
Questions?