Bridle Herding Efficiency of a Survey Bottom Trawl with Different Bridle Lengths

Philip J. Politis and Timothy J. Miller
Bridle Herding Efficiency Field Experiments

- Objectives
  - Quantify species and length specific bridle herding efficiency of the NEFSC standard survey bottom trawl gear
  - Examine diel differences in bridle herding efficiency
  - Focus on Georges Bank flatfish
  - Observe flatfish behavioral response along survey trawl bridle and at the ground-gear via underwater video

- 19 sea days completed during fall 2014 aboard the F/V Karen Elizabeth
  - September 15 – 24, 10 days (Eastern Georges and Cultivator Shoals)
    - Bridle efficiency experiments only
  - September 29 – October 7, 9 days (South of Martha’s Vineyard)
    - Bridle efficiency and underwater video
Methods – Field Experiment

• Compare catch between three lengths of bridles
  • Equivalent 12fm increases in bridle length – Standard (20fm), Medium (32fm), Long (44fm)
  • Assumption that increased catch is proportional to the increase area swept by the bridles

• 1 – Standard Length – 36.6m
  • 12°
  • DS=32m WS=13m
  • Area door=59264m²
  • Area wing=24076m²

• 2 – Medium Length – 58.2m
  • 12°
  • DS=41m WS=13m
  • Area door=75932m²
  • Area wing=24076m²

• 3 – Long Length – 80.5m
  • 12°
  • DS=50m WS=13m
  • Area door=92600m²
  • Area wing=24076m²
Methods – Field Experiment

• Randomized Block Design
  • Each block assumed unique and uniform fish density, physical parameters (temp, light, bottom etc.)
  • Randomized towing order of configurations
  • 3 tows per block (each bridle length towed once)

• Towing Protocols
  • NEFSC standard speed and duration – 20min @ 3.0kts
  • 20min on-bottom tow duration – determined by net mensuration
  • Consistent setting and hauling procedures throughout study
  • Offset tows by 0.25nm
  • Direction of tows – attempted minimize current effects
  • 24hr operations
    • All tows within a block were completed under the same day/night condition
    • Full sun down and full sun up
Methods – Field Experiment

• Consistent Trawl Geometry
  • Used restrictor rope between large, oversized trawl doors
  • 7/8” Samson UltraBlue - buoyant
    • Lengths adjusted to achieve target spread
    • Confident the bridle remained off-bottom

• Gear and Environmental Parameters Measured
  • Door and wing spread, trawl depth – ITI sensors
  • Speed of ground and depth – GPS and EK60
Methods – Bridle Configurations

1 – Standard Length – 36.6m
   - 12°
   - DS=32m WS=13m
   - Area door=59264m²
   - Area wing=24076m²

2 – Medium Length – 58.2m
   - 12°
   - DS=41m WS=13m
   - Area door=75932m²
   - Area wing=24076m²

3 – Long Length – 80.5m
   - 12°
   - DS=50m WS=13m
   - Area door=92600m²
   - Area wing=24076m²
Methods – Data Analysis: Model 1

• Estimate bridle efficiency by modeling the catch as a function of the proportion of fish in the path of the net actually captured by the net plus the proportion of fish in the path of the bridle width captured (Somerton & Munro 2001)
  • Block, gear configuration and fish length specific
  
  \[ N_{ijl} = E_{il}D_{il}A_{ij} + E_{il}D_{il}E_{il}A_{b} + \varepsilon \]

Subscripts
  
  \[ i = \text{block} \]
  \[ j = \text{bridle length configuration} \]
  \[ l = \text{fish length class} \]
  \[ \varepsilon = \text{error term} \]

• \( D_{il} \) and \( E_{il} \) assumed constant within a block but vary between blocks
• \( A_{ij} \) and \( A_{b} \) are measured values
• \( D_{il} \) and \( E_{il} \) combined, \( k \), to reduce the number of parameters to be estimated
• Parameters estimated by non-linear least squares

\[ N_{ijl} = k_{il}A_{ij} + k_{il}E_{il}A_{b} + \varepsilon \]
Methods – Data Analysis: Model 2

- Condition on total catch per block to reduce the number of parameters to be estimated
  - Parameters estimated by maximum likelihood

- Expected proportion of catch for an individual gear configuration given the total catch of all gear configurations within a block is expressed as:

$$E\{N_{ij} | N_i\} = \frac{E_n D_i A_n_{ij} + E_n D_i E_b A_b_{ij}}{\sum_i(E_n D_i A_n_{ij} + E_n D_i E_b A_b_{ij})}$$

- Net efficiency, $E_n$, and fish density, $D$, terms cancel out
- Net and bridle area swept values, $A_n$ and $A_b$, are measured values
- Efficiency of the bridle, $E_b$, is the only parameter to be estimated

$$E\{N_{ijl} | N_{il}\} = \frac{A_n_{ij} + E_b A_b_{ij}}{\sum_i(A_n_{ij} + E_b A_b_{ij})}$$
Results

• 73 total representative blocks
  • 41 day, 32 night
  • All yellowtail measured (no subsampling)

• Current was a significant issue around Eastern Georges Bank
  • All tows made in the same direction as current direction for the remainder of the study

• Tows and blocks did overlap due to availability of fish and current issues
  • Mainly eastern Georges Bank
  • Current and fish distribution was less of a concern at Cultivator Shoals and South of Martha’s Vineyard

• Obtained data for six species of flatfish
  • Yellowtail flounder – 4062 lengths
  • Winter flounder – 2834 lengths
  • Summer flounder – 2933 lengths
  • Fourspot flounder – 3892 lengths
  • Windowpane flounder – 2148 lengths
  • Gulfstream flounder – 14130 lengths
  • Mixed skates, Scallops, Goosefish, Lobster – Weights obtained starting block 33
Results – Tow Locations
**Results**

- Consistent trawl geometry and bridle angles between blocks, bridle length configurations and areas sampled

<table>
<thead>
<tr>
<th>AREA</th>
<th>Gear Configuration</th>
<th>Bridle Length (m)</th>
<th>Total Blocks</th>
<th>Day Blocks</th>
<th>Night Blocks</th>
<th>Mean Depth (m)</th>
<th>Door Spread (m)</th>
<th>Wing Spread (m)</th>
<th>Bridle Angle (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastern Georges</td>
<td>Standard</td>
<td>46.6</td>
<td>37</td>
<td>23</td>
<td>14</td>
<td>68.7</td>
<td>33.1 ±0.3</td>
<td>12.8 ±0.3</td>
<td>12.6 ±0.3</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>69</td>
<td>37</td>
<td>23</td>
<td>14</td>
<td>68.2</td>
<td>42.8 ±0.7</td>
<td>13.0 ±0.3</td>
<td>12.5 ±0.3</td>
</tr>
<tr>
<td></td>
<td>Long</td>
<td>91</td>
<td>37</td>
<td>23</td>
<td>14</td>
<td>68.4</td>
<td>51.2 ±1.1</td>
<td>13.1 ±0.5</td>
<td>12.1 ±0.3</td>
</tr>
<tr>
<td>Cultivator Shoals</td>
<td>Standard</td>
<td>46.6</td>
<td>10</td>
<td>7</td>
<td>3</td>
<td>59.2</td>
<td>33.0 ±0.2</td>
<td>12.6 ±0.3</td>
<td>12.6 ±0.3</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>69</td>
<td>10</td>
<td>7</td>
<td>3</td>
<td>59.4</td>
<td>42.6 ±0.5</td>
<td>13.3 ±0.3</td>
<td>12.2 ±0.2</td>
</tr>
<tr>
<td></td>
<td>Long</td>
<td>91</td>
<td>10</td>
<td>7</td>
<td>3</td>
<td>59.8</td>
<td>51.5 ±0.6</td>
<td>13.4 ±0.4</td>
<td>12.1 ±0.2</td>
</tr>
<tr>
<td>South of Martha's</td>
<td>Standard</td>
<td>46.6</td>
<td>26</td>
<td>11</td>
<td>15</td>
<td>42.5</td>
<td>32.8 ±0.1</td>
<td>12.7 ±0.2</td>
<td>12.5 ±0.1</td>
</tr>
<tr>
<td></td>
<td>Vineyard</td>
<td>69</td>
<td>26</td>
<td>11</td>
<td>15</td>
<td>42.5</td>
<td>42.3 ±0.4</td>
<td>13.1 ±0.4</td>
<td>12.2 ±0.2</td>
</tr>
<tr>
<td></td>
<td>Long</td>
<td>91</td>
<td>26</td>
<td>11</td>
<td>15</td>
<td>43.1</td>
<td>50.4 ±0.7</td>
<td>13.2 ±0.4</td>
<td>11.8 ±0.2</td>
</tr>
</tbody>
</table>
### Results – Flatfish Catch Per Block

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>Blocks</th>
<th>Day Blocks</th>
<th>Night Blocks</th>
<th>TotalFish</th>
<th>Mean Catch</th>
<th>Pct Caught Day</th>
<th>Pct Caught Night</th>
<th>Mean Catch Per Block Day</th>
<th>Mean Catch Per Block Night</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellowtail Flounder</td>
<td>51</td>
<td>22</td>
<td>29</td>
<td>4062</td>
<td>79.6</td>
<td>0.52</td>
<td>0.48</td>
<td>96.4</td>
<td>66.9</td>
</tr>
<tr>
<td>Winter Flounder</td>
<td>46</td>
<td>28</td>
<td>18</td>
<td>2834</td>
<td>61.6</td>
<td>0.43</td>
<td>0.57</td>
<td>43.5</td>
<td>89.7</td>
</tr>
<tr>
<td>Summer Flounder</td>
<td>36</td>
<td>18</td>
<td>18</td>
<td>2933</td>
<td>81.5</td>
<td>0.29</td>
<td>0.71</td>
<td>46.8</td>
<td>116.2</td>
</tr>
<tr>
<td>Fourspot Flounder</td>
<td>63</td>
<td>31</td>
<td>32</td>
<td>3892</td>
<td>61.8</td>
<td>0.24</td>
<td>0.76</td>
<td>30.1</td>
<td>92.4</td>
</tr>
<tr>
<td>Windowpane Flounder</td>
<td>28</td>
<td>13</td>
<td>15</td>
<td>2148</td>
<td>76.7</td>
<td>0.13</td>
<td>0.87</td>
<td>21.5</td>
<td>124.5</td>
</tr>
<tr>
<td>Gulfstream Flounder</td>
<td>20</td>
<td>5</td>
<td>15</td>
<td>14130</td>
<td>706.5</td>
<td>0.01</td>
<td>0.99</td>
<td>39.8</td>
<td>928.7</td>
</tr>
</tbody>
</table>

- Mean catch per block higher during the day for yellowtail flounder
Results – Catch Proportions Combined, Day and Night: Yellowtail Flounder

51 Blocks – 22 Day\29 Night

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Std</th>
<th>Med</th>
<th>Long</th>
<th>PropSTD</th>
<th>PropMED</th>
<th>PropLNG</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>4062</td>
<td>1194</td>
<td>1372</td>
<td>1496</td>
<td>0.29</td>
<td>0.34</td>
<td>0.37</td>
</tr>
<tr>
<td>Day</td>
<td>2121</td>
<td>754</td>
<td>665</td>
<td>702</td>
<td>0.36</td>
<td>0.31</td>
<td>0.33</td>
</tr>
<tr>
<td>Night</td>
<td>1941</td>
<td>440</td>
<td>707</td>
<td>794</td>
<td>0.23</td>
<td>0.36</td>
<td>0.41</td>
</tr>
</tbody>
</table>

ANOVA Treatment=Bridle Length

<table>
<thead>
<tr>
<th>Day/Night</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>0.25</td>
</tr>
<tr>
<td>Day</td>
<td>0.8</td>
</tr>
<tr>
<td>Night</td>
<td>0.03*</td>
</tr>
</tbody>
</table>

ANOVA Treatment=Bridle Length Day/Night p-value

0.25

0.8

0.03*
Results

• Proportion of yellowtail fl increased with increasing bridle length both combined and during night blocks

• Increase of yellowtail fl catch was not observed during day block when extending from the standard length to the medium length bridle

• Significant difference in number of yellowtail fl captured between bridle length configurations at night only

• Similar day and night length frequencies for yellowtail fl
  • More smaller fish captured during night blocks
**Results – Parameter Estimates – Yellowtail Flounder**

Parameter estimates were poor for all species. Estimates ofEb for yellowtail fl converged only when all data were combined.

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>Model 1 Fit by NLS</th>
<th>Model 2 Fit by NLL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nij = ki<em>Anij + ki</em>Eb*Abij</td>
<td>Nij/Ni= Anij + Eb<em>Abij/∑(Anij+Eb</em>Abij)</td>
</tr>
<tr>
<td>Yellowtail Fl All</td>
<td>Eb</td>
<td>Variance</td>
</tr>
<tr>
<td></td>
<td>0.15</td>
<td>1.26</td>
</tr>
<tr>
<td>Yellowtail Fl Day</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Yellowtail Fl Night</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>
Results – Length Specific Parameter Estimates – Yellowtail Flounder

- Length specific parameter estimates were poor as well

<table>
<thead>
<tr>
<th>Size Class (cm)</th>
<th>Model 1 Fit by NLS</th>
<th>Model 2 Fit by NLL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nijl = kil<em>Anij + kil</em>Ebl*Abijl</td>
<td>Nijl/Nil = Anij + Ebl<em>Abijl/∑(Anij+Ebl</em>Abijl)</td>
</tr>
<tr>
<td></td>
<td>Eb</td>
<td>Variance</td>
</tr>
<tr>
<td>Yellowtail Fl All</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16-32</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>32-36</td>
<td>0.35</td>
<td>0.94</td>
</tr>
<tr>
<td>36-40</td>
<td>0.1</td>
<td>1.29</td>
</tr>
<tr>
<td>40-52</td>
<td>0.04</td>
<td>3.66</td>
</tr>
<tr>
<td>Yellowtail Fl Day</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16-32</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>32-36</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>36-40</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>40-52</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Yellowtail Fl Night</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16-32</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>32-36</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>36-40</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>40-52</td>
<td>0.12</td>
<td>1.5</td>
</tr>
</tbody>
</table>
Results – Length Specific Catch Ratios – Yellowtail Flounder
Results – Underwater Video Observations

• 20 tows with underwater cameras
  • South of Martha’s Vineyard and Vineyard Sound

• Water clarity and limited ambient light affected video quality
  • Species identification is problematic
  • Several videos are unusable

• Few fish observed in the majority of video

• Camera was unstable mounted on bridles
  • Video orientation is difficult to determine

• Video evidence of bridles light on the bottom
  • Some observations of skates and possibly summer flounder reacting to the bridle
Results – Underwater Video Observations

- Camera mounted on middle bridle, pointed downward towards the lower bridle
  - Lower bridle bottom contact is intermittent
Results – Underwater Video Observations

• Camera mounted on lower bridle approximately 2m forward of the bunt bobbin, pointed aft towards the wing-end
  • This portion of lower bridle is off-bottom
Results – Underwater Video Observations

- Camera mounted on middle bridle, pointed downward towards the lower bridle
  - Fish observed reacting and moving away from the lower bridle
Bridle Bottom Contact

- Inconsistent shine along wire
- Minimal shine on longest bridle
Discussion

• Diel Catch Differences
  • Higher catch per block of yellowtail flounder during day blocks
    • Different than the other flatfish species
  • Possibly affected by high sampling intensity of a small area on eastern Georges Bank

• Yellowtail length frequencies were similar for each bridle length
  • Increased catch of smaller sizes for at night
    • Likely due to rockhopper sweep efficiency

• Yellowtail flounder catch increased with increasing bridle length only during night blocks
  • Differs from other research (Walsh, 1988; Glass & Wardle, 1989; Wardle, 1993)
  • Suggest another influential factor on these results
Discussion

- Shine pattern suggests longest bridle had minimal bottom contact
  - Unknown bottom contact for standard and medium bridle lengths
  - May help to explain observed catch ratio differences between medium and long bridle lengths
  - Video supports bridle bottom contact is intermittent

- Attempted corrections for effective bridle herding lengths did not alter results
  - Convergence issues remain

- Estimated of bridle herding efficiency from this study are poor
  - May have been affected by limited numbers and distribution of fish
  - Several blocks and tows within a block on eastern Georges Bank sampled over the same bottom
    - May have affected fish behavior and density in that area
Discussion

- In order to fully understand the bridle herding efficiency of the NEFSC survey bottom trawl it is critical to determine the actual length and region of the bridle in contact with the bottom

- Lack of consistent bottom contact of the lower bridle is likely a significant factor limiting the daytime herding of flatfish for the NEFSC standard survey trawl gear

- The portion of lower bridle extending from the wing-ends are a potential area of significant flatfish escapement minimizing the effective herding efficiency of the standard survey bridles
  - Further work should be done to observe and quantify fish escapement in this region of the survey trawl gear