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Migration and Upstream Passage for Juvenile Eel

Zahra Anwar
University of Massachusetts Amherst

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USGS Leetown Science Center, S.O. Conte Anadromous Fish Research Laboratory

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Migration and Upstream Passage for Juvenile Eel

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Turners Falls, Massachusetts
Acknowledgements

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Introduction
American Eel (Anguilla rostrata)

American eel life cycle

Number of eels ascending the eel ladder per day at the Moses-Saunders dam in the upper St. Lawrence River at Cornwall, Ontario, during the 31 day summer peak migration period between 1974 and 2005 (from J.M. Casselman, OMNR).

Eel Pass Design and Geometry

Important parameters:
- Location
- Length
- Durability
- Substrate
- Slope
- Attraction flow
Substrate Types

Top Left: Vertical cylinder substrate (Milieu, Inc)
Top Right: Brush substrate (Cottam Brush LLC)
Bottom Left: Vertical Stud substrate (“studliner”)
Bottom Right: Geotextile (3M Enkamat)

Commercially produced substrate (Milieu, Inc.)
Experimental Set Up

Parameters to be explored:

• Substrate roughness
• Slope
• Fish Length
• Fish Weight
• Temperature
• Days in Captivity

V shaped Substrates have many advantages, such as providing a wetted margin and also providing protection against flooding that renders flat substrates useless.

CAD rendering of ramp structure showing base pivot for varying slope (brown rod) and overhead camera array.
Tilting ramp structure with five substrates of varying roughness (range of grain sizes in red text). A manifold provides water flow for each substrate separately.
Climbing Behaviors

Elvers (~100 mm TL) climbing fine (left) and coarse (right) substrates.
Length-Weight Relationships of Test Eels

![Graph showing length-weight relationships for glass eels and elvers. The x-axis represents length (mm) ranging from 40 to 160, and the y-axis represents weight (g) ranging from 0.0 to 4.0. Two distinct clusters are visible, one for glass eels and another for elvers.](image-url)
## Range of Testing and Results

<table>
<thead>
<tr>
<th></th>
<th>Size (mm)</th>
<th>Weight (g)</th>
<th>Temp (C)</th>
<th>Date</th>
<th>Specimens Tested</th>
<th>Attempted</th>
<th>Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass</td>
<td>50-69</td>
<td>0.038-0.28</td>
<td>12-23</td>
<td>11 May - 17 Jun</td>
<td>301</td>
<td>38</td>
<td>148</td>
</tr>
<tr>
<td>Elver</td>
<td>90-147</td>
<td>0.6-3.6</td>
<td>22-28</td>
<td>7 Jul - 23 Aug</td>
<td>299</td>
<td>20</td>
<td>251</td>
</tr>
</tbody>
</table>
## VariableDefinitions

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
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</thead>
<tbody>
<tr>
<td>$D_{\text{max}}$</td>
<td>Maximum vertical distance (x) reached</td>
</tr>
<tr>
<td>$T_{\text{start}}$</td>
<td>Start of first attempt</td>
</tr>
<tr>
<td>$T_{\text{end}}$</td>
<td>End of last attempt</td>
</tr>
<tr>
<td>$T_{\text{starta}}$</td>
<td>Start of $D_{\text{max}}$ attempt</td>
</tr>
<tr>
<td>$T_{\text{enda}}$</td>
<td>End of $D_{\text{max}}$ attempt</td>
</tr>
<tr>
<td>$T_{\text{max}}$</td>
<td>Time at $D_{\text{max}}$</td>
</tr>
<tr>
<td>$T_{\text{fatigue}}$</td>
<td>$T_{\text{start}}$ to $T_{\text{end}}$ (censored for passers)</td>
</tr>
<tr>
<td>$T_{\text{ramp}}$</td>
<td>Total time on ramp across all attempts</td>
</tr>
<tr>
<td>$T_{\text{test}}$</td>
<td>Total test time</td>
</tr>
</tbody>
</table>
Example Tracks

Number of Attempts = 1
Example Tracks

Number of Attempts = 2
$D_{\text{max}}$ - Percent Success – Glass Eels

Ramp Slope = 25°

Ramp Slope = 35°

Ramp Slope = 45°
$D_{\text{max}}$ - Percent Success – Elvers

Ramp Slope = 25°

Ramp Slope = 35°

Ramp Slope = 45°
\( \text{D}_{\text{max}} - \text{Slope and Substrate Box Plots - Glass Eels} \)

- \( \text{D}_{\text{max}} \) (m) range from 0.0 to 0.5.
- The graph shows box plots for different slopes (25, 35, 45 degrees) and substrates.
- The interquartile range (IQR) and median lines are indicated for each condition.
- The mean values are represented by squares.

### Table:

<table>
<thead>
<tr>
<th>Slope</th>
<th>Substrate</th>
<th>25</th>
<th>35</th>
<th>45</th>
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<tr>
<td>25</td>
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<tr>
<td></td>
<td>4</td>
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<tr>
<td></td>
<td>5</td>
<td>25</td>
<td>35</td>
<td>45</td>
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</tbody>
</table>


**D_{max} – Slope and Substrate Box Plots – Elvers**

![Graph showing D_{max} values for different slopes and substrates.](image)

- **Slope and Substrate** Box Plots
- **Range in 1.5 InterQuartile**
- **Mean**

<table>
<thead>
<tr>
<th>Slope</th>
<th>Substrate</th>
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<tbody>
<tr>
<td>25</td>
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<td>2</td>
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### Cox Regression Analysis Results - Glass Eels

<table>
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<tr>
<th>Independent Variable</th>
<th>Significant</th>
<th>Pr&gt;ChiSqr</th>
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<tbody>
<tr>
<td><em>T</em>&lt;sub&gt;max&lt;/sub&gt;</td>
<td>Substrate</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>Captivity</td>
<td>0.0272</td>
</tr>
<tr>
<td></td>
<td>Weight</td>
<td>0.0312</td>
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<tr>
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<tr>
<td></td>
<td>Weight</td>
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<tr>
<td><em>Rate</em></td>
<td>Substrate</td>
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<tr>
<td></td>
<td>Captivity</td>
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<tr>
<td><em>T</em>&lt;sub&gt;start&lt;/sub&gt;</td>
<td>Substrate</td>
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<tr>
<td></td>
<td>Captivity</td>
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## Cox Survival Analysis Results – Elvers

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<th>Pr&gt;ChiSqr</th>
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</thead>
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<td>Slope</td>
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<td></td>
<td>Weight</td>
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<td></td>
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<td>Dmax</td>
<td>Substrate</td>
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<tr>
<td></td>
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<tr>
<td></td>
<td>Substrate</td>
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<tr>
<td>Tstart</td>
<td>Slope</td>
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<td></td>
<td>Substrate</td>
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<td></td>
<td>Captivity</td>
<td>0.0056</td>
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Conclusions

• For glass eels, substrate roughness has a significant effect on climbing attempt rate and $D_{\text{max}}$
• For elvers substrate and slope have an effect on $D_{\text{max}}$ and $T_{\text{max}}$ with substrate having a more significant effect
• The rougher substrates have better performance
• Substrate slope may or may not have a significant effect between $25^\circ$ and $45^\circ$ (more analysis needed)
## Number of Attempts – Elvers

<table>
<thead>
<tr>
<th>Number of Attempts</th>
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<td>3</td>
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<tr>
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<table>
<thead>
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<th>25°</th>
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<tr>
<td>Substrate 5 (rough)</td>
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<tr>
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<td>Substrate 3</td>
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<tr>
<td>Substrate 2</td>
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<td>0</td>
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<tr>
<td>Substrate 1 (smooth)</td>
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### Number of Attempts – Glass Eels

<table>
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<td>0</td>
</tr>
<tr>
<td>1</td>
<td>18</td>
<td>20</td>
<td>15</td>
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<tr>
<td>2 - 4</td>
<td>3</td>
<td>2</td>
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<tr>
<td>&gt;4</td>
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#### Substrate 5 (rough)

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<td>2 - 4</td>
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#### Substrate 4

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<tr>
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<td>11</td>
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<tr>
<td>2 - 4</td>
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<td>11</td>
</tr>
<tr>
<td>&gt;4</td>
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<td>5</td>
<td>4</td>
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#### Substrate 3

<table>
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</tr>
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#### Substrate 2

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</tr>
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#### Substrate 1 (smooth)

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<th>45°</th>
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<td>1</td>
<td>0</td>
</tr>
<tr>
<td>&gt;4</td>
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