Size-selective mortality and bioenergetic limitations of juvenile steelhead under different freshwater environmental constraints in the Skagit River, Washington

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Early growth influences survival of steelhead.
Constraints on growth in freshwater

- **Sampled**: Food Ration
- **Estimated**: Feeding Rate
- **Sampled**: Water Temperature

Flow

LWD: Structure/Refuge

Substrate: Structure/Refuge

Predator Presence

Less-Optimal Foraging/Refuge

Optimal Foraging/Refuge
<table>
<thead>
<tr>
<th>Model Inputs</th>
<th>The Bioenergetics Model</th>
<th>Model Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Thermal experience</td>
<td>Energy Out: Metabolism + Waste + Growth</td>
<td>Estimated Energy In (given observed Growth &amp; other input values)</td>
</tr>
<tr>
<td>- Temporal diet composition</td>
<td></td>
<td>Estimated as...</td>
</tr>
<tr>
<td>- Consumer growth (G)</td>
<td></td>
<td>Feeding Rate ($%C_{max}$) or...</td>
</tr>
<tr>
<td>- Predator energy density</td>
<td></td>
<td>Consumption (g of prey/day)</td>
</tr>
<tr>
<td>- Prey energy density</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Data collection: Growth (FL-to-weight)

Juveniles

Smolts

Adults

Fork length (mm)
Adult sample: 25% $C_{\text{max}}$
Smolt sample: 24% $C_{\text{max}}$
Juvenile sample: 23% $C_{\text{max}}$

Adult sample: 27% $C_{\text{max}}$
Smolt sample: 25% $C_{\text{max}}$
No Juvenile sample

**POOR DIET**
65% of annual growth

73% annual growth

WEIGHT LOSS

4281

4293

3472

POOR DIET

3° C

Adult sample: 24% $C_{\text{max}}$
Smolt sample: 24% $C_{\text{max}}$
Juvenile sample: 22% $C_{\text{max}}$

Adult sample: 26% $C_{\text{max}}$
Smolt sample: 26% $C_{\text{max}}$
Juvenile sample: 26% $C_{\text{max}}$
49% of annual growth

HOT

LIMITED ACCESS TO QUALITY FEEDING HABITAT?

WIDE DISPARITY

GREAT DIET

WIDEDISPARITY

COLD

Adult sample: 25% $C_{\text{max}}$
Smolt sample: 22% $C_{\text{max}}$
Juvenile sample: 21% $C_{\text{max}}$

Adult sample: 28% $C_{\text{max}}$
Smolt sample: 25% $C_{\text{max}}$
Juvenile sample: 23% $C_{\text{max}}$
Conclusions

1) Early growth influences survival during later life stages

2) Water temperature, consumption, feeding rate, and prey energy density affect growth differently according to the local environment

3) **Usefulness**: If freshwater SSM is significant, evaluating and improving growth in freshwater habitats could be a useful tool for recovery

4) **Usefulness**: Bioenergetics modeling can help identify the main factors inhibiting growth
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