Juvenile Coho Salmonid Energy Expenditure in a Turbulent Flow Field

EISI REU Summer 2014 Final Presentation

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Hydraulic Variables

- **TKE**

  \[
  \text{TKE} = 0.5 \left( \sigma_x^2 + \sigma_y^2 + \sigma_z^2 \right)
  \]

  \( \sigma \) is the standard deviation of the velocity in a given direction.

- **Strain**

  \[
  \text{Strain} \ (s^{-1}) = \sqrt{\left( \frac{u_{i+1} - u_i}{x_{i+1} - x_i} \right)^2 + \left( \frac{v_{i+1} - v_i}{y_{i+1} - y_i} \right)^2 + \left( \frac{w_{i+1} - w_i}{z_{i+1} - z_i} \right)^2}
  \]
## Energy Expenditure Equations

<table>
<thead>
<tr>
<th>Metabolism Total (Joules/Day)</th>
<th>( = \text{Standard} + \text{Activity} )</th>
<th>InSTREAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Metabolism (Joules/Day)</td>
<td>( = (30 \times W^{0.784}) \times e^{(0.0693 \times T)} )</td>
<td>InSTREAM</td>
</tr>
<tr>
<td>Active Metabolism (Joules/Day)</td>
<td>( = (\text{feedTime}/24) \times [e^{(0.03 \times V)} - 1] \times \text{Standard} )</td>
<td>InSTREAM</td>
</tr>
<tr>
<td>Feed Time (hours)</td>
<td>( = \text{dayLength} + 2 )</td>
<td>InSTREAM</td>
</tr>
<tr>
<td>Weight (grams)</td>
<td>( = 0.0134 \times L^{2.96} )</td>
<td>InSTREAM Van Winkle et al. (1996)</td>
</tr>
</tbody>
</table>

\( L = \text{Fish Length (cm)} \quad W = \text{Fish weight (g)} \quad V = \text{Swimming Speed (m/s)} \)
The Standard Methodology

- Use a current meter to measure the velocity of the water at 2/3 the depth of the thalweg
- Single point measurement
- Assumes the fish swims at the speed of the flow
The Effect of TKE on Energy Expenditure For Fish of Different Sizes

- **Fish Size Range (cm)**
  - 6.2 – 7.0
  - 7.0 – 8.0
  - 8.0 – 9.0
  - 9.0 – 10.0

- **Equation Type**
  - Exponential

- **Slope**
  - 26.00
  - 41.27
  - 31.93
  - 27.38

- **Intercept**
  - 136.72
  - 196.95
  - 287.45
  - 353.40

- **R²**
  - 0.41
  - 0.61
  - 0.74
  - 0.68

For different size ranges of fish, the energy expenditure (in Joules per Day) is modeled using exponential equations, with varying slopes and intercepts. The R² values indicate the proportion of variance explained by the models, with higher values indicating better fit.
The Influence of Strain On Energy Expenditure

Fish Length Range 7.0 - 8.0 cm
Correlation of Hydraulic Variables:
Effect of Velocity on TKE

\[ y = 0.02x + 0.00 \]
\[ R^2 = 0.71 \]
Vector Method of Modeling Swimming Speed Compared to the Standard Method of Measuring Swimming Speed

- Assumes that fish swim in a line from point to point
- Takes into account fish motion

Vector Model Compared to The Standard Method
Swimming Speed Measured from Tail-beat frequency
Velocity Independent Method Compared to the Standard

Swimming speed

\[ V = \frac{(L \times (f - 2.0 \times L^{-1/3}))}{1.56} \]

L = Fish Length (cm)  \quad W = Fish Weight (g)  \quad T = Water Temperature (°C)
\[ V = \text{Swimming Velocity (cm/s)} \quad f = \text{Tail-beat Frequency (beats/s)} \]

Webb 1984
Results

• Fish of different sizes do not discriminate habitat based on TKE values
• Larger fish expend more energy for a given TKE value
• Fish may exhibit a threshold TKE
• Using the standard method for swimming speed the relationship is predictable
• Standard method over-estimates the TRUE fish swimming speed
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