Fine-scale taxonomic and spatiotemporal variability in the energy density of prey for juvenile Chinook Salmon (*Oncorhynchus tshawytscha*)

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- Energetic content varies considerably between organisms.
- Determined by composition of:
  - Lipid
  - Protein
  - Carbohydrate
- Quantifying energy content of species or groups can be important to explain ecological phenomena.
How do we measure energy density?

- Direct measurement via bomb calorimetry
How do we measure energy density?

• Direct measurement via bomb calorimetry

• Challenges:
  • Time consuming
  • Expensive
  • Unable to measure small organisms (< 25 mg dry-weight)

• Alternative Methods:
  • Mathematically derive from chemical composition
  • Infer energy density from dry-weight
How do we measure energy density?

Hartman & Brandt (1995)

James et al. (2012)
How do we measure energy density?

Ash weight contributes to dry mass but not to energetic content!
Model Development

• Data Collection:
  • Search all studies that investigated energy density
  • Measured energy density directly via bomb calorimetry
  • Measured ash-free dry weight & at least one other predictor

• Predictors:
  • % Ash-free dry weight (AFDW)
  • % Dry weight (DW)
  • % Protein Content
  • % Lipid Content
Model Development

• Analysis:
  • Develop linear models between predictors and ED
  • Included differences between disparate taxonomic groups using binary dummy variables
  • Compare models using Akaike’s Information Criterion, corrected for small sample sizes (AICc)
Weil et al. *In Review*

![Graph showing the relationship between Log10 Energy Density (KJ/g Wet Weight) and Log10 Percent Ash-Free Dry Weight. The graph includes data points for Aquatic Invertebrates, Aquatic Vertebrates, Aquatic Plants & Algae, and Terrestrial Invertebrates. The R^2 value is 0.97.]
Model Development – Binary Dummy Variables

• Adding Dummy Variables:
  • Aquatic Invertebrates (AI)
  • Aquatic Vertebrates (AV)
  • Terrestrial Invertebrates (TI)
  • Aquatic Plants and Algae (APA)
  • Aquatic Animals (AA)
  • Animals (AN)

= 8 model combinations including one w/o dummy var.

= 3 additional model combinations

= 11 Candidate models for each predictor
Conclusions

- Ash-free dry weight is a superior predictor to estimate energy density compared to all other metrics

\[
\log_{10}(ED) = 1.07 \times \log_{10}(AFDW) - 0.80
\]

Aquatic Animals $\rightarrow$ + 0.09
Terrestrial Invertebrates $\rightarrow$ + 0.04

- Model is robust across species and ecosystems

Weil et al. In Review
Applications
Growth ~ Prey Quantity * Prey Quality
Growth \sim \text{Prey Quantity} \times \text{Prey Quality}

- When analyzing prey quality, several assumptions are regularly made

\begin{itemize}
  \item \textit{Hyperia medusarum}
  \item \textit{Cyphocaris challengeri}
  \item \textit{Themisto pacifica}
\end{itemize}
1. Does **taxonomic variability** in energy density (ED) exist on a fine-scale within invertebrate prey groups?
2. Does **seasonal variability** in ED of prey exist over the course of the early marine period for salmon?
3. Does spatial variability in ED exist on a fine-scale for species within the same marine basin?
• Monthly zooplankton sampling (▲) April to September in 3 locations – Maple Bay, Cowichan Bay & Saanich Inlet
• Opportunistic dipnet fish sampling (■) in June/July in 2 locations – Oak Bay Flats & Patricia Bay
Species ID:

- Wet Weight
- Dry Weight
- Ash Weight
Species ID:

\[ \log_{10}(ED) = 1.07 \cdot \log_{10}(AFDW) - 0.80 \]

Aquatic Animals \( \rightarrow + 0.09 \)
Terrestrial Invertebrates \( \rightarrow + 0.04 \)
Taxonomic Differences – Decapod Larvae
Taxonomic Differences – Amphipods

![Graph showing energy density (J/g Wet weight) for different species: H. medusarum, T. pacifica, C. challengerii. The graph compares energy density among species and sex (female and male).](image)
Temporal Differences

Energy Density (J/g Wet Weight)

Month

A) 

B) 

C) 

D) 

E) 

F)
Spatial Differences

A) Energy Density (J/g Wet Weight)

B) Location

C) Saanich, Cowichan, Maple

D) Saanich, Cowichan, Maple
Conclusions

- **Ash-free dry weight** is a superior metric to estimate energy density across a wide taxonomic range of organisms.

- Significant **taxonomic variability exists** between ED of prey groups important to juvenile Chinook Salmon:
  - Decapod zoeae and megalopae as well as amphipods show substantial differences between groups/species.

- Seasonal **temporal variability exists** for some groups, but patterns are not consistent.

- We did not detect variation in ED on a local scale.
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