Evaluation of the application of empirical growth rate models toward a long-term zooplankton biomass/production time-series on the southern shelf of Vancouver Island

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Develop practical models for estimating zooplankton production from time-series observations

- **Advantage #1:**
  Good long-term biomass time series coverage for the N. Pacific and Global Ocean

- **Advantage #2:**
  Retrospective *community-level* production rates estimates
Zooplankton Production Rate Estimates

ZP = Biomass X Daily growth rate

Relatively simple calculation requirements:
- Biomass estimated from microscopic analysis of plankton net casts
- Daily growth rates estimated using empirical equations

But.....

\( \text{var}(B) \gg \text{var}(g) \)...

Q: Are we really describing variation of ZP? Or just replacing units?

(Huntley and Lopez. Am. Nat. 1992)
Zooplankton Production Rate Estimates

- Structural Equation Modelling (SEM); 83 Boreal Lakes
- Chitobiase method: no plankton nets required
- Q: Does community-level ZP vary in the same way as population-level-ZP?  
  ➢ A: Yes/No
- Q: How important is biomass?  
  ➢ A: Moderate importance e.g. Chl a and Temp. act directly on ZP but not on Biomass

Broad-scale production rate patterns

1. Sampling July’08, July’09, and October’09

2. Production rates varied in space (0.15-4 mg C m\(^{-3}\) d\(^{-1}\))

3. Production rates varied significantly with temperature and phytoplankton biomass \((r^2=0.67, p<0.001)\)
Objectives:

• Apply size-specific somatic growth rates ($g$) to long-term biomass time series

• Estimate $g$ using 4 empirical models (increasing complexity):
  - Huntley and Lopez (1992) == HLO
  - Ikeda and Motoda (1985) == IM
  - Hirst and Lampitt (1998) == HLA
  - Hirst and Bunker (2003) == HB

• Estimate zooplankton production (ZP) for each model

• Assess variation in each ZP estimate relative to biomass
  - Simple residual squared error comparison (Annual)

• Compare subset of model-ZP estimates to chitobiase estimates
SVI Shelf Biomass Time Series

• SVI started 1979

• This study = 1985-2015

• Spring/Early Summer (May, June, July)

• Late summer/Fall (Aug., Sept., Oct.)

• **6-9 shelf stations/cruise**

• Max. extracted Chl. $a$ used for phytoplankton biomass
1. ‘Northern’ vs. ‘Southern’ biomass $\approx$ cold vs. warm

2. Temporal patterns influence higher trophic level survival (Mackas et al. 2007)

3. Difficult to translate biomass patterns to quantitative estimates of food web efficiency

(Galbraith & Young *in*: Chandler, King, and Boldt 2016, Can. Tech. Fish. Aquat. Sci.)
Empirical Models: HLO

- Model data set = lab and field $g$ and Temp. estimates
- $g$ and Temp. estimated over the course of a generation
- Not exactly ‘instantaneous’
- Assumes food-saturation
- **Requires: Temperature**

$$g = 0.0445 e^{0.111T}$$

Empirical Models: IM

- **Physiological method**: $O_2$ uptake for 7 phyla; 163 spp.
- Respiration rate $\sim$ Body size across habitat temperatures
- Broadly applicable; not just copepods
- Can be further applied to estimate $g$; Ikeda and Motoda (1985)
- **Requires**: Temp. & $BW_j$

Empirical Models: HLA

- Empirical method: synthesis of 100’s of MR field incubations
- Growth rate ~ Body size & spawning type across habitat temperatures
- **Distinguishes between broadcast & sac-spawning copepods**
- Applicable to juvenile copepods
- **Requires: Temp., BW, spawn type**

Empirical Models: HB

- Empirical method: synthesis of 100’s of MR field incubations

- Growth rate ~ Body size, spawning type & [Phyto.] across habitat temperatures

- **Distinguishes between broadcast & sac-spawning copepods**

- Assumes diet of > 5μm phyto. cells.

- **Requires: Temp., BW_i, spawn. type & [Chl a]**

• Patterns of total spring/summer SVI shelf biomass not as clearly aligned with climatology as biomass of ‘southern’ and ‘subarctic’ species
Results: HLO

• Mean production rate = 19.8 (~0 – 480) mg C m^{-2} d^{-1}

• Variation mostly described by biomass (expected); $R^2_{adj} = 0.90$, $p<0.001$

• Residual square error = 10.31
Results: IM

- Mean production rate = 17.7 (~0 – 327) mg C m$^{-2}$ d$^{-1}$
- Variation mostly described by biomass (expected); $R^2_{adj.} = 0.98$, $p< 0.001$
- Residual square error = 3.21
Results: HLA

- Mean production rate = 12.70 (~0 – 185) mg C m^{-2} d^{-1}

- Variation mostly described by biomass (expected); $R^2_{adj} = 0.89$, $p< 0.001$

- Residual square error = 5.21
Results: HB

- Mean production rate = 66.46 (~2.2 – 379) mg C m\(^{-2}\) d\(^{-1}\)

- Variation mostly described by biomass (expected); \(R^2_{\text{adj.}} = 0.88, p<0.001\)

- Residual square error = 22.97
How Do the Models Compare?

- No explicit relationship between production rate and model RSE
- Increasing complexity = greater RSE with inclusion of body size
- RSE for HLO; unexpected. Decoupling between biomass and temperature?
1. Temporal patterns of southern copepod and ctenophore biomass anomaly similar to crustacean zooplankton production rates.


(Chitobiase-production rates: Sastri, Suchy, Venello unpublished.)
Summary

1. All models generated reasonable production rate estimates.

2. Variation in biomass exerts a strong influence on predicted production rates.

3. Production rates estimated with IM and HLA are mostly described by biomass; however, easy to apply.

4. Variation of community-level production rates may not be described by same factors describing variation at population- and individual-level.

5. Model choice depends on objectives: Exercise caution when applying to dynamic and/or extreme conditions.