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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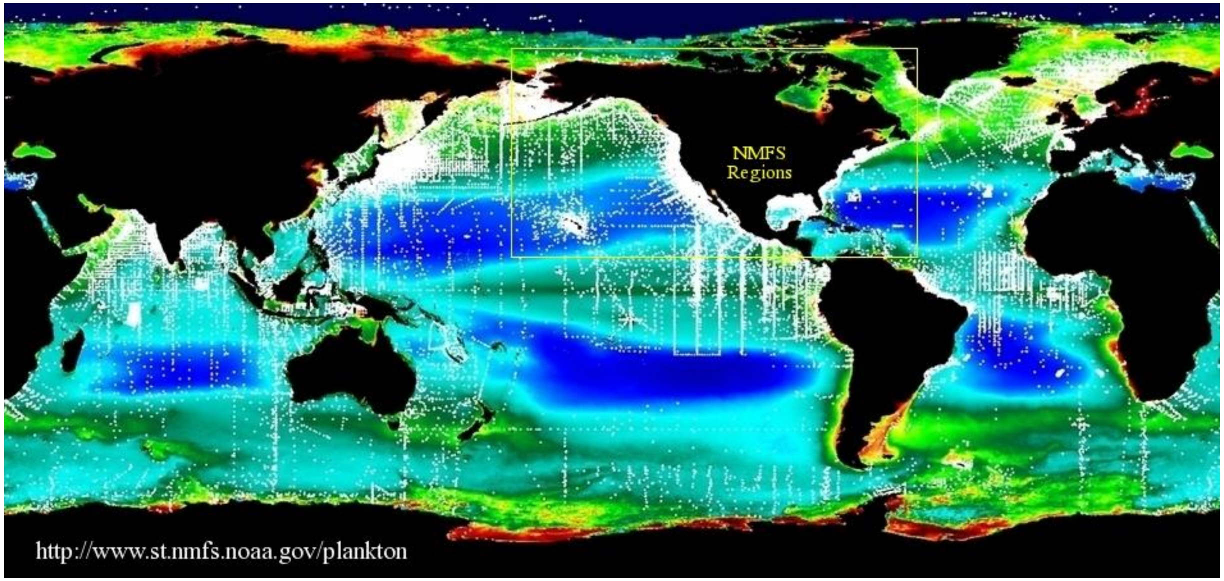
WG37: Term of Reference #3

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

<u>Relatively simple calculation requirements</u>:

- Biomass estimated from microscopic analysis of plankton net casts
- Daily growth rates estimated using empirical equations

But…..

var(B) >>> var (g)…

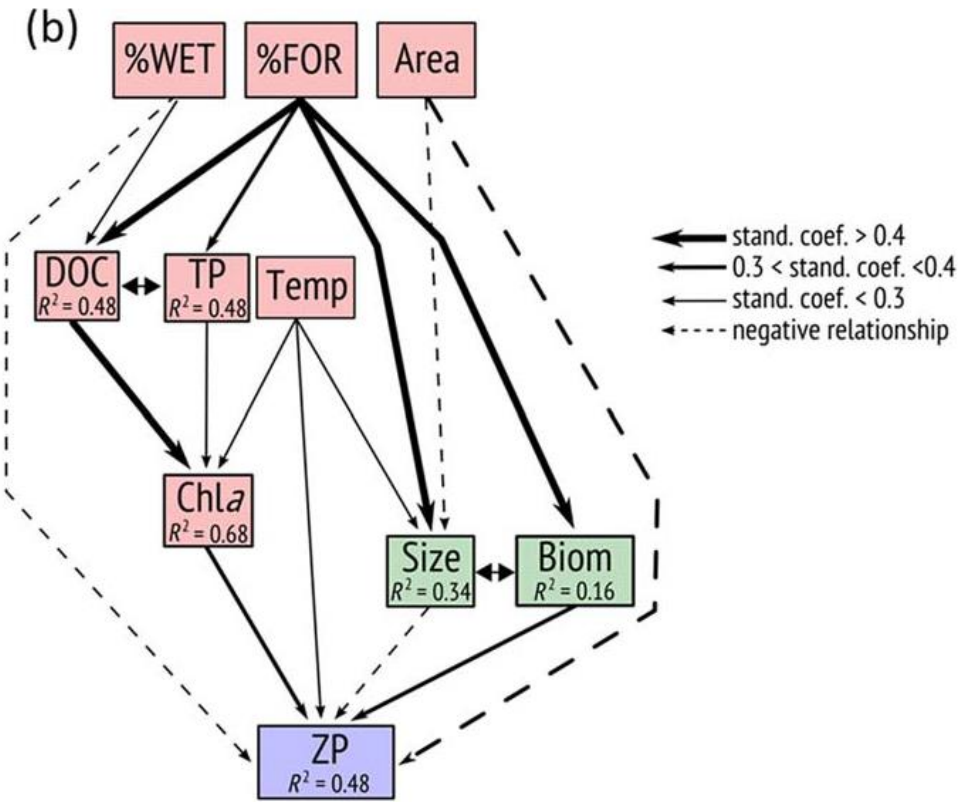
Q: Are we really describing variation of ZP? Or just replacing units?

AMOUNT OF EXPECTED VARIABILITY IN BIOMASS ON SCALES APPROPRIATE TO POPULATION DYNAMICS COMPARED TO THAT IN GROWTH RATE

Criterion on Which Variability Is Based	Expected Variability Factor
For biomass:	
Scale:	
Temporal (days–months)	100
Vertical (10–100 m)	1,000
Horizontal (1–10 km)	100
For growth rate:	
Temperature:	
−1°C	.060
28°C	.212

(Huntley and Lopez. *Am.Nat*. 1992)

Zooplankton Production Rate Estimates



- Structural Equation Modelling (SEM); 83 Boreal Lakes
- Chitobiase method: no plankton nets required

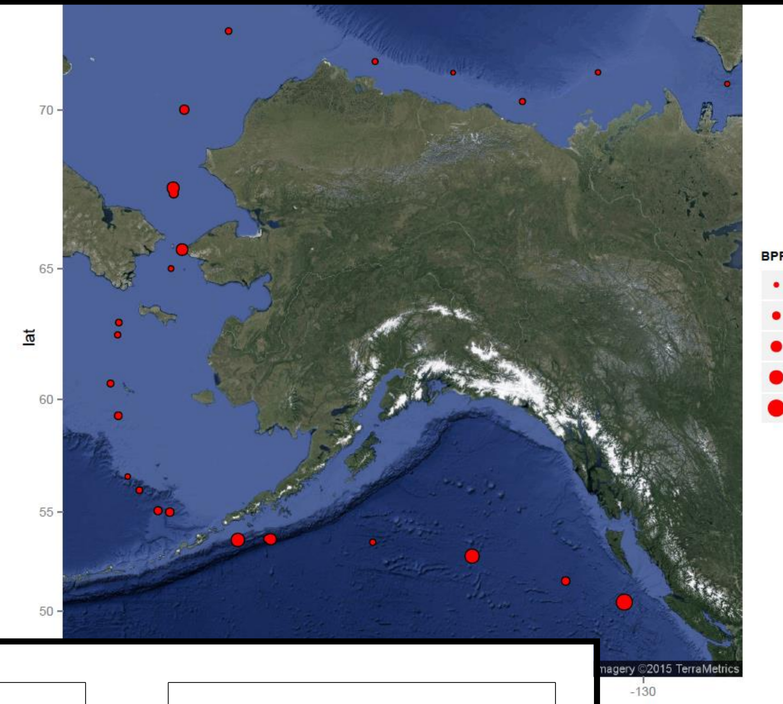
- Q: Does community-level ZP vary in the same way as population-level-ZP?
  - A: Yes/No

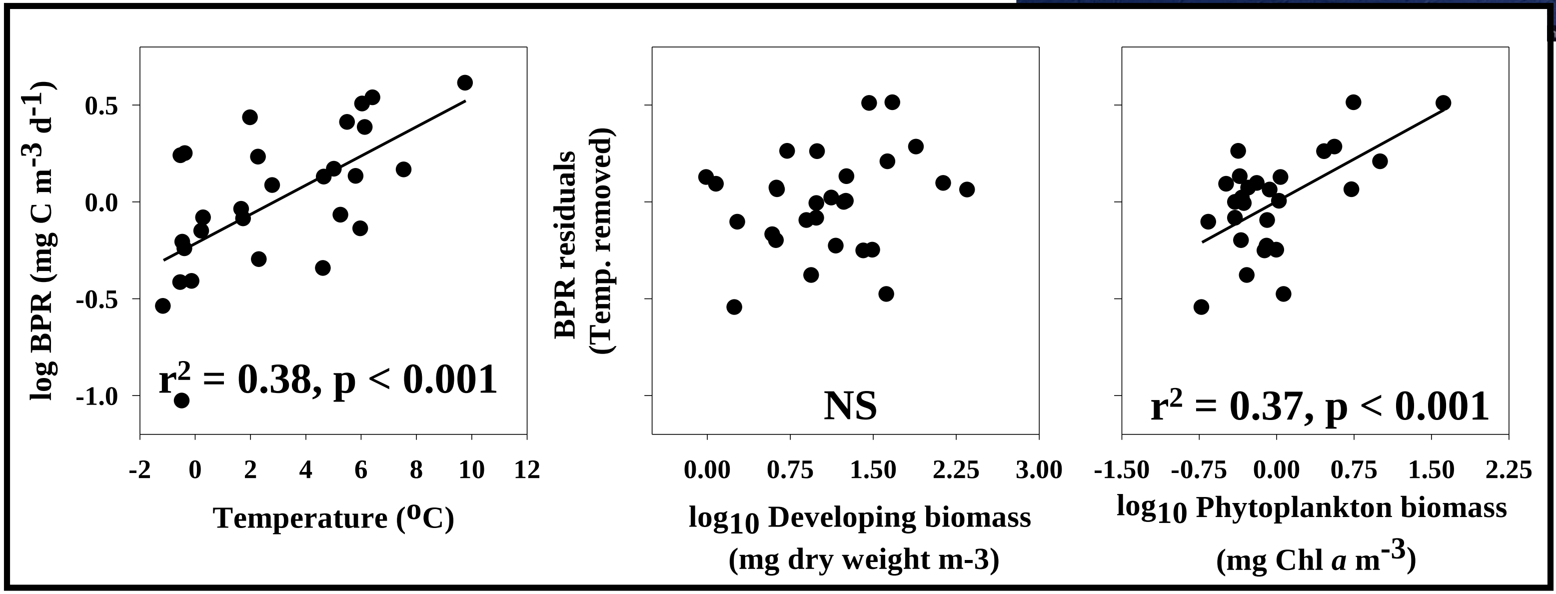
- Q: How important is biomass?
  - A: Moderate importance e.g. Chl a and Temp. act *directly* on ZP but not on Biomass

(Fortin-St. Gelais, Sastri, del Giorgio, and Beisner. *Limnol.Oceanogr.Lett.* 2017)

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)





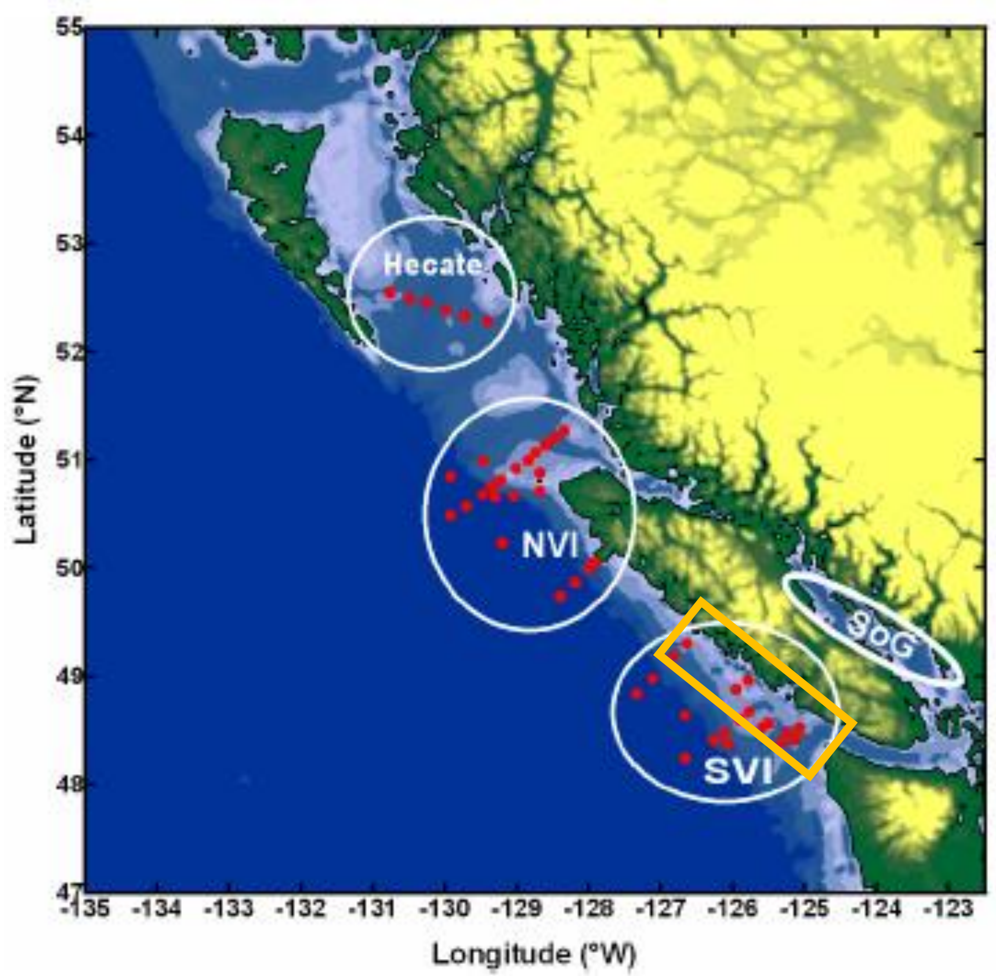
(Sastri et al. *J. Exp. Mar. Ecol. Biol.* 2012)

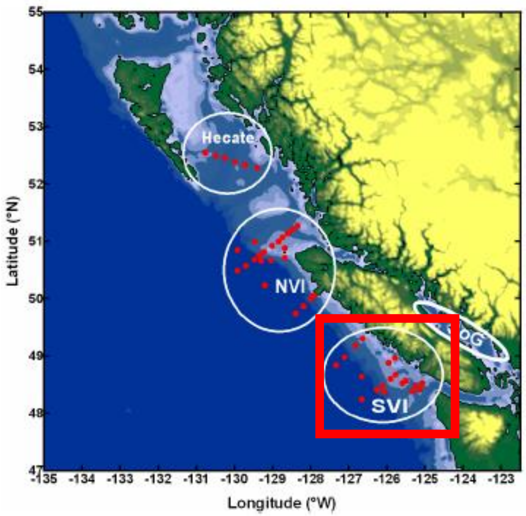
Objectives:

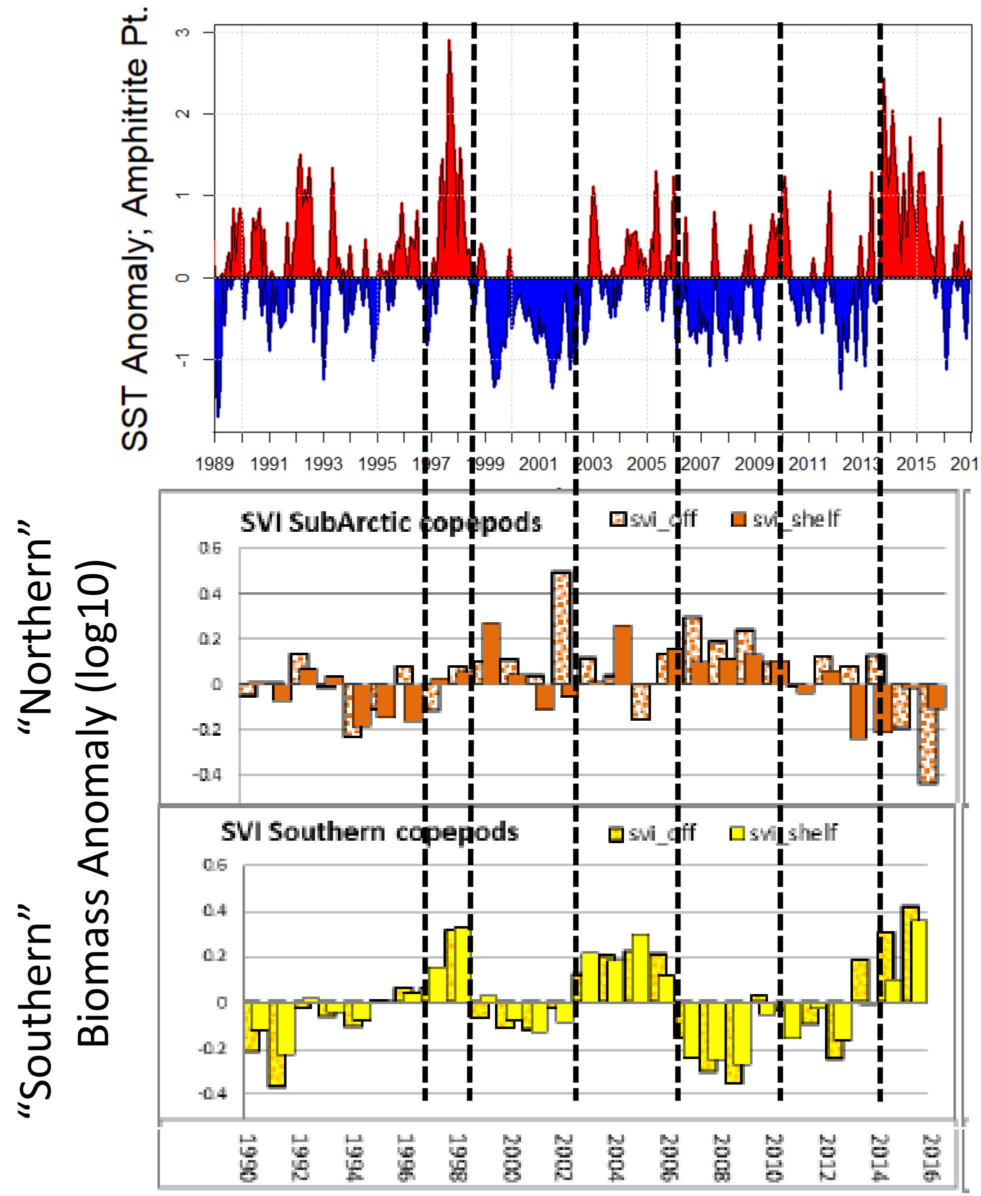
- Apply size-specific somatic growth rates(***g***) to long-term biomass time series
- Estimate ***g*** using 4 empirical models (increasing complexity):
  - ➢ Huntley and Lopez (1992) == HLO
  - ➢ Ikeda and Motoda (1985) == IM
  - ➢ Hirst and Lampitt (1998) == HLA
  - ➢ Hirst and Bunker (2003) == HB
- 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







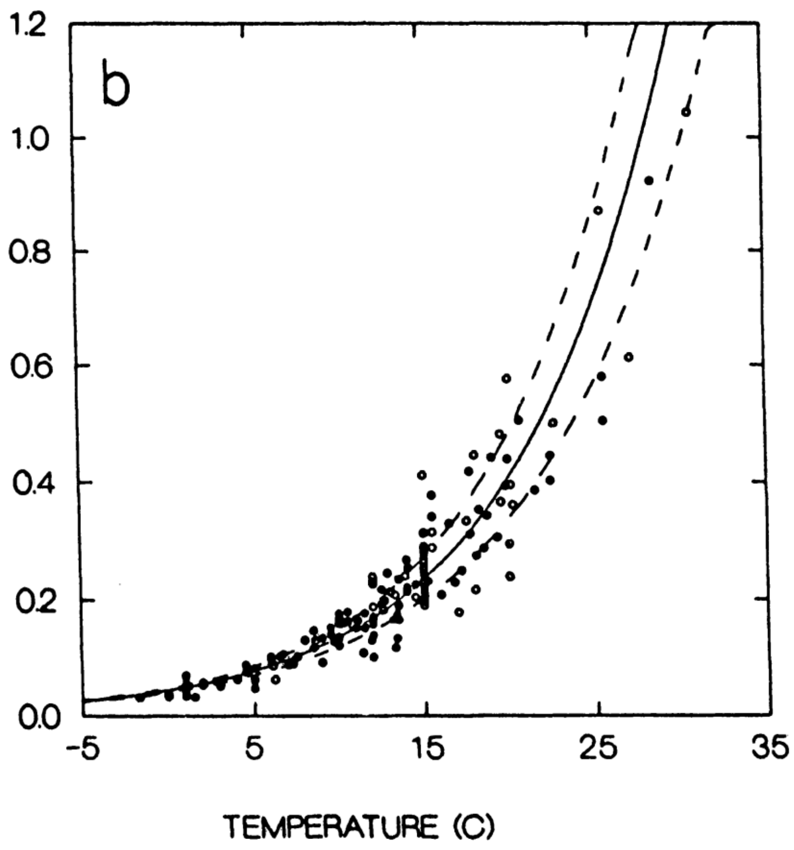
1. **‘Northern’ vs. ‘Southern’ biomass ≈ cold vs. warm**

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

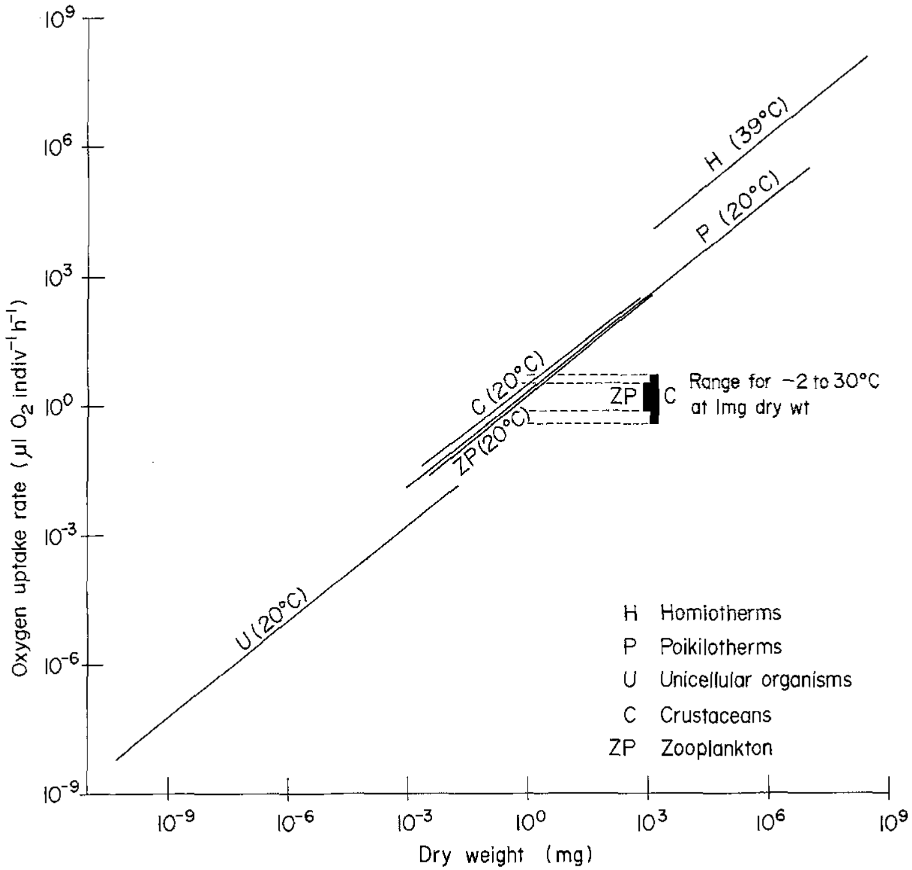


$$g = 0.0445\, e^{0.111\,T}$$

- 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
- **<u>Requires: Temperature</u>**

(Huntley and Lopez. *Am.Nat*. 1992)

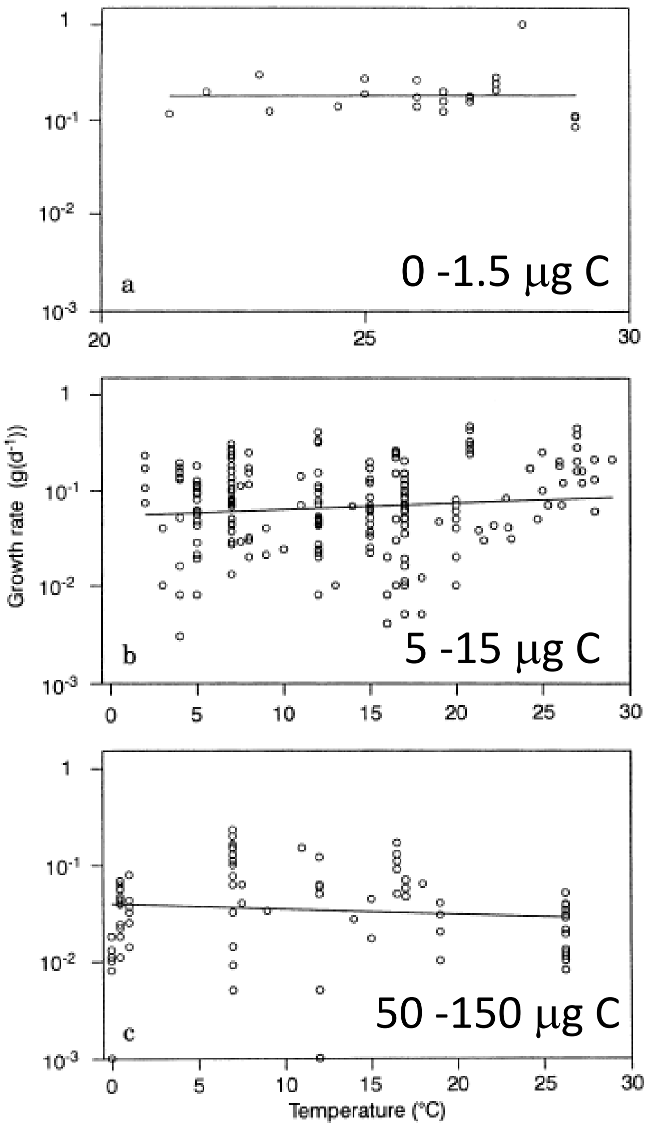
Empirical Models: IM



(Ikeda. *Mar.Biol*. 1985)

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

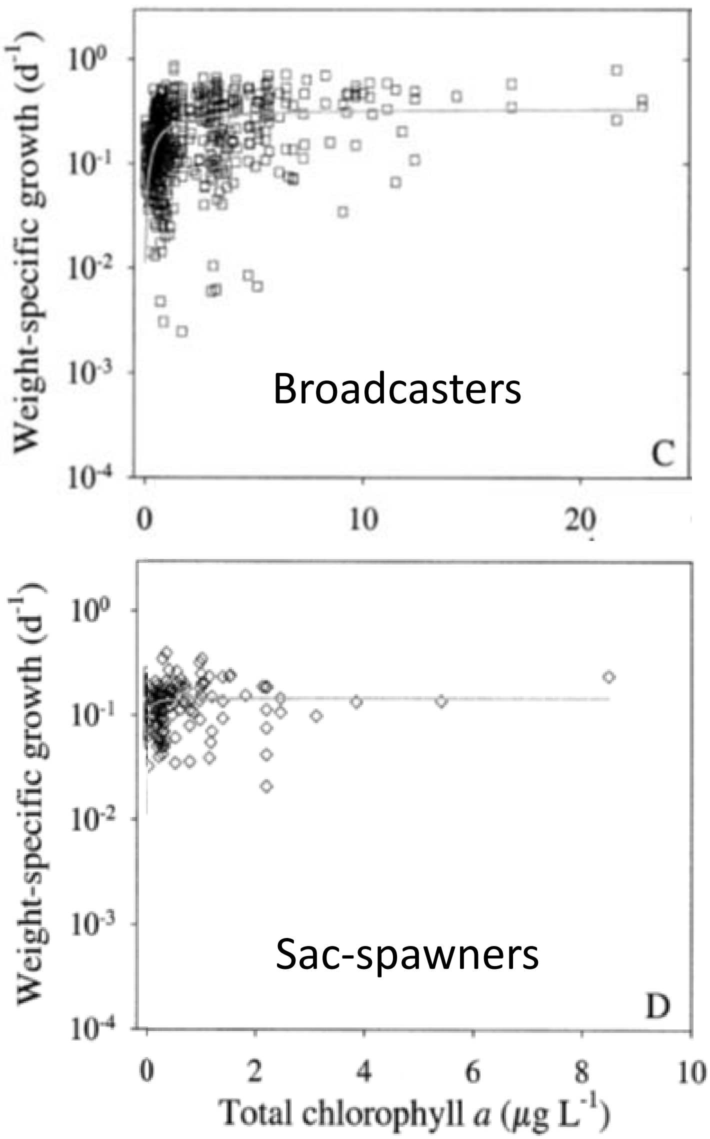
Empirical Models: HLA



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

(Hirst & Lampitt. *Mar.Biol*. 1998)

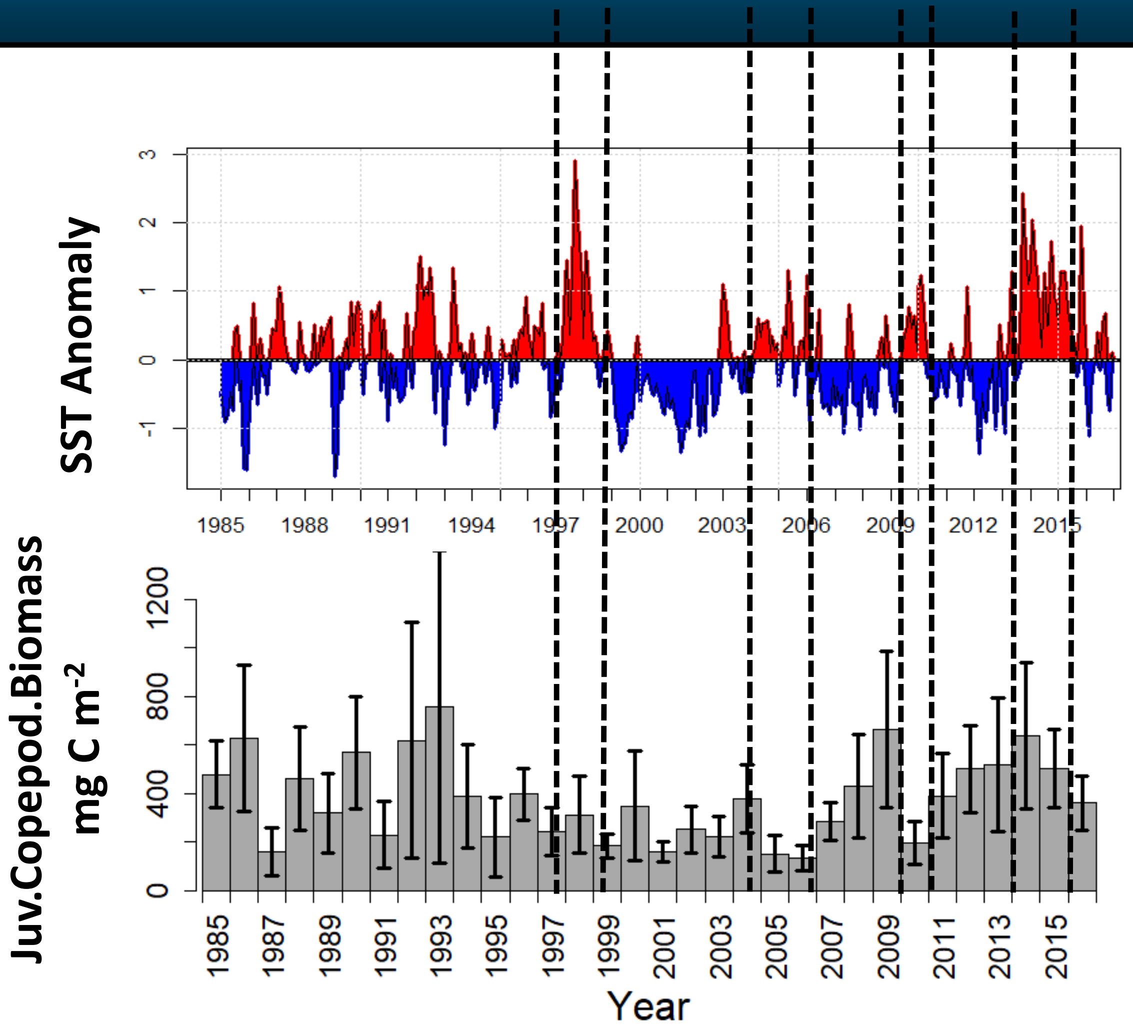
Empirical Models: HB

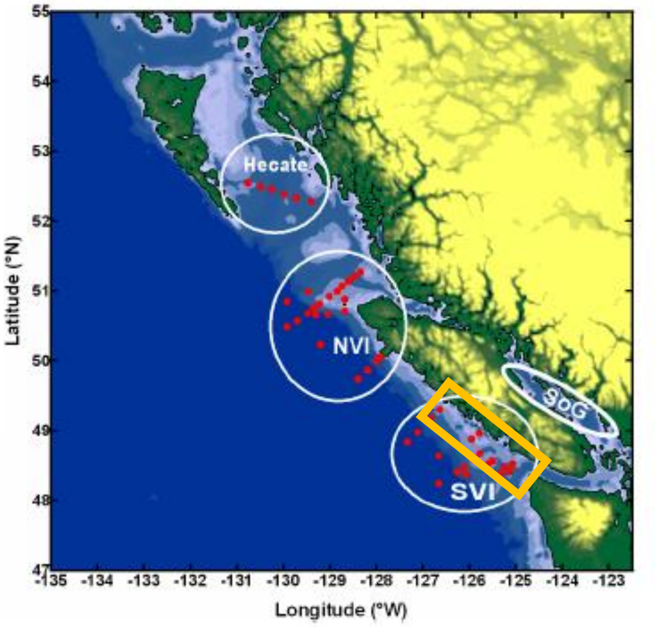


(Hirst & Bunker. *Limnol.Oceanogr.* 2003)

- 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*]**

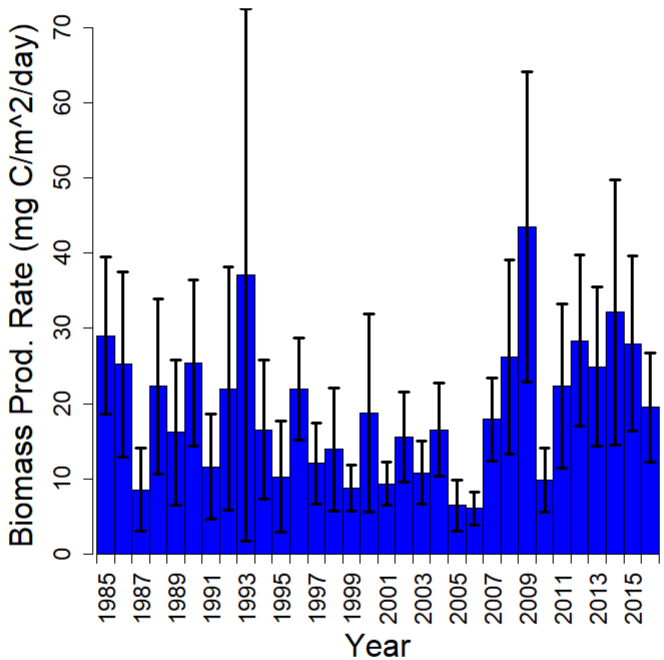
Results: Biomass Time Series

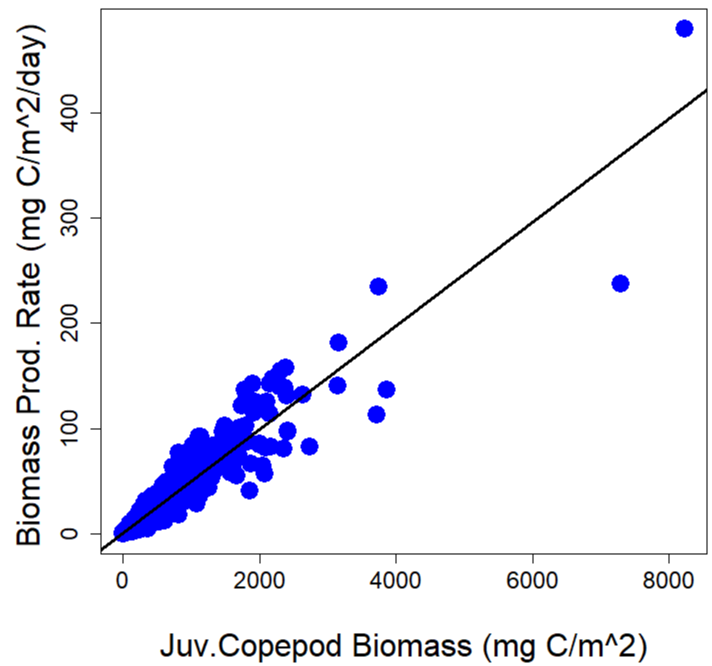




- Patterns of total spring/summer SVI shelf biomass not as clearly aligned with climatology as biomass of 'southern' and 'subarctic' species

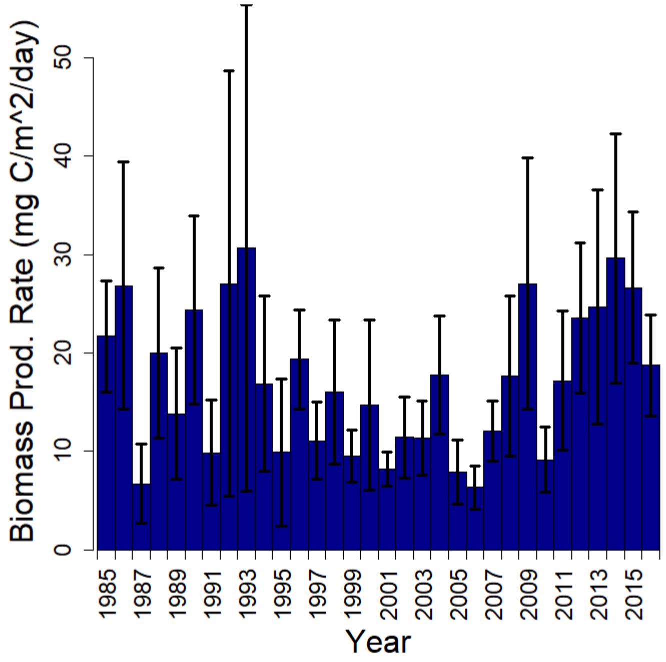
Results: HLO

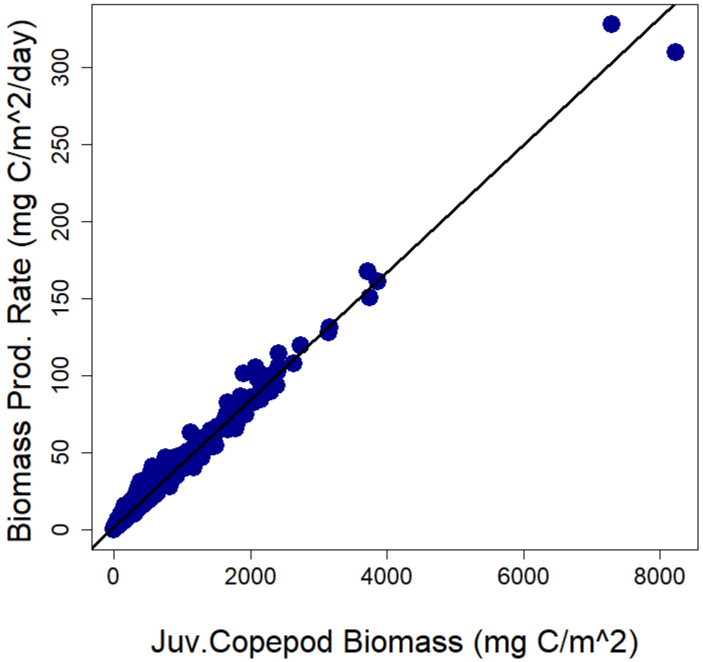




- Mean production rate = 19.8 (~0 – 480) mg C m^{-2} d^{-1}
- Variation mostly described by biomass (expected); $R^2_{adj.}$ = 0.90, $p < 0.001$
- Residual square error = 10.31

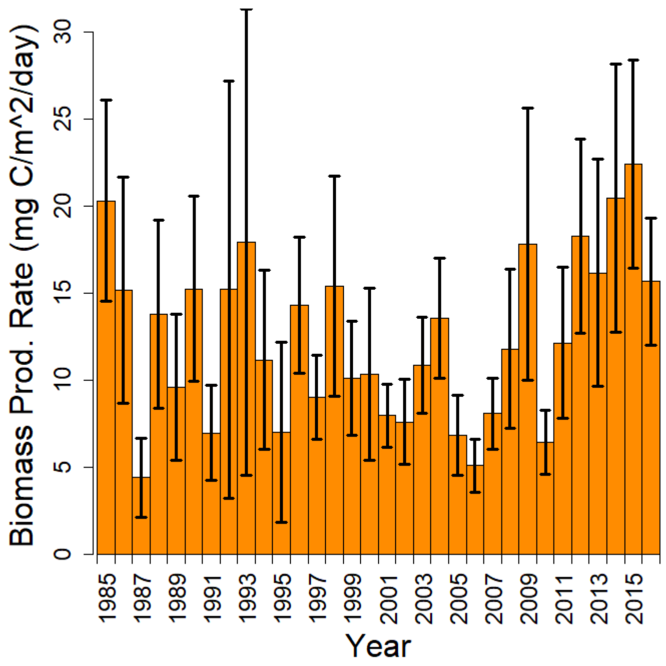
Results: IM

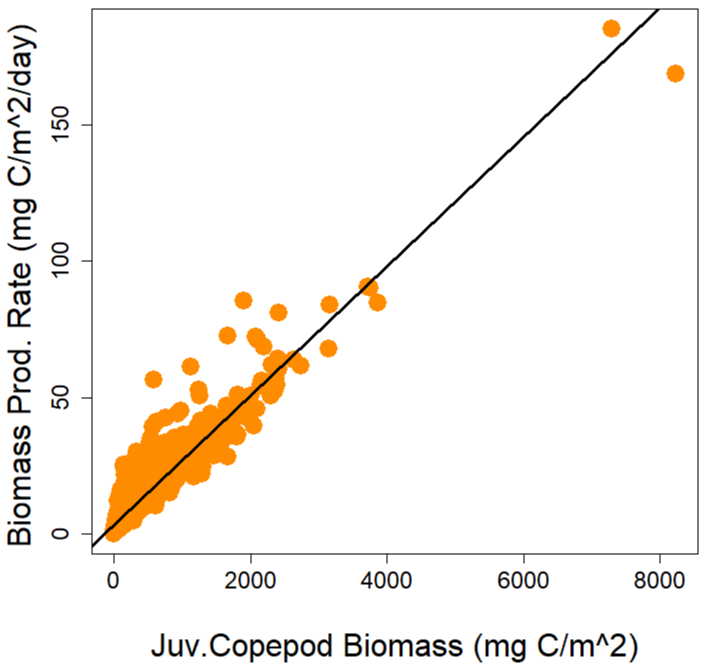




- Mean production rate = 17.7 (~0 – 327) mg C m^{-2} d^{-1}
- Variation mostly described by biomass (expected); $R^2_{adj.}$ = 0.98, $p < 0.001$
- Residual square error = 3.21

Results: HLA



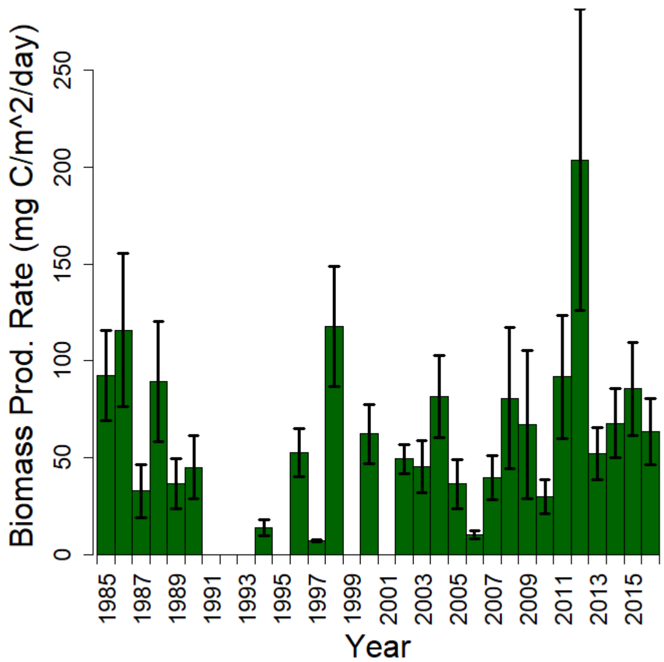


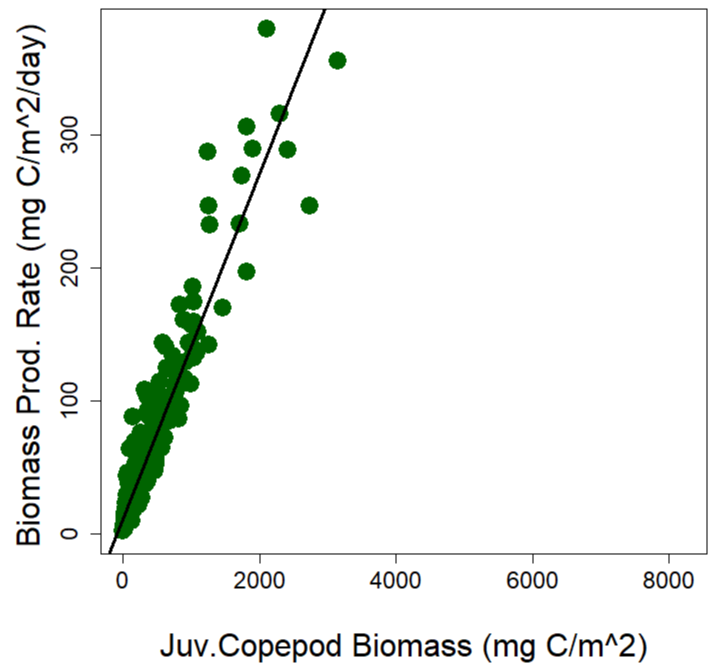
- Mean production rate = 12.70 (~0 – 185) mg C m^{-2} d^{-1}

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

- Residual square error = 5.21

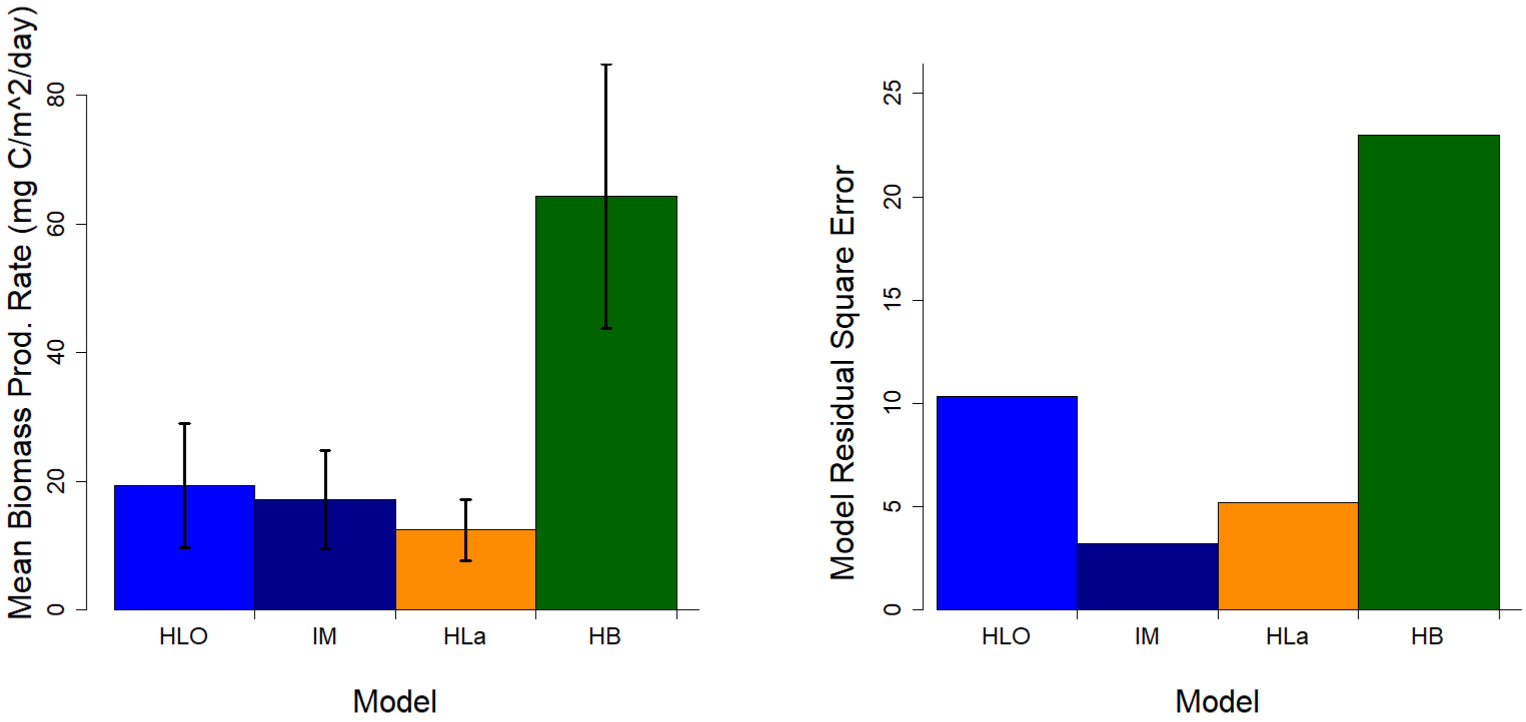
Results: HB





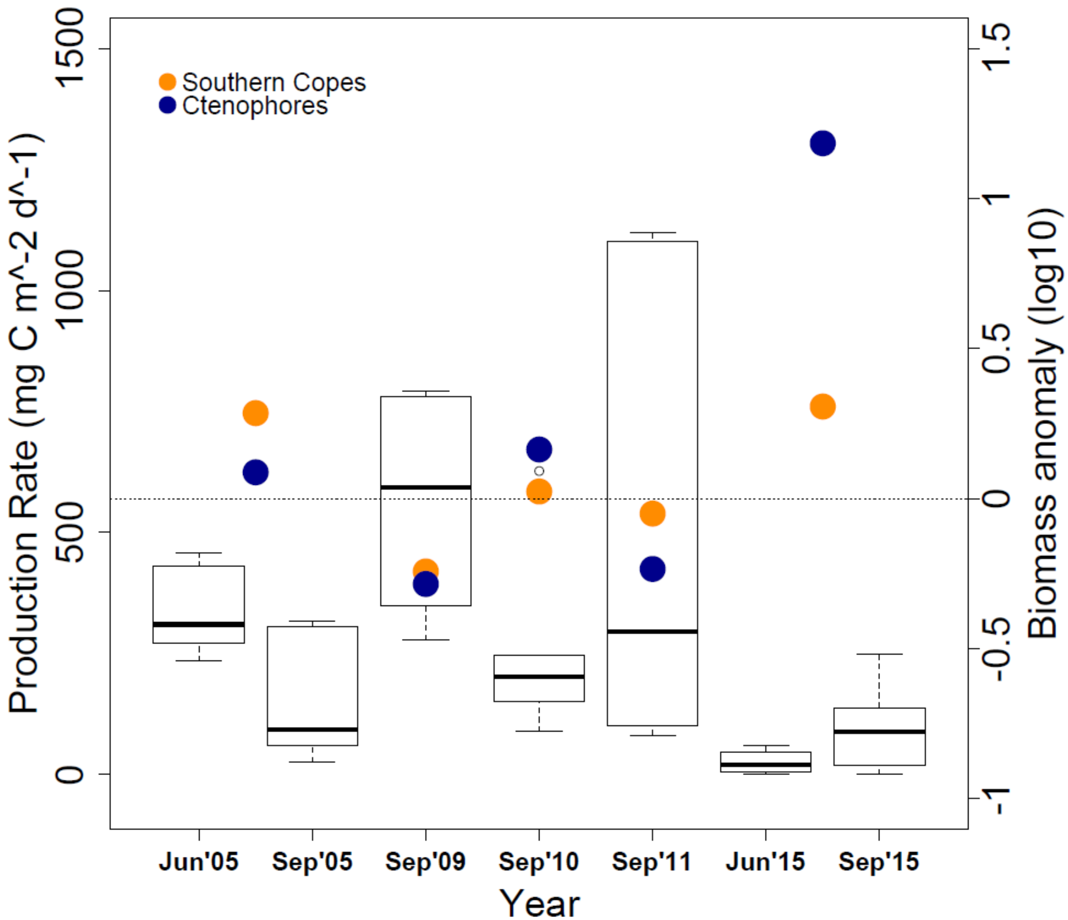
- Mean production rate = 66.46 (~2.2 – 379) mg C m^{-2} d^{-1}
- Variation mostly described by biomass (expected); $R^2_{adj.}$ = 0.88, $p < 0.001$
- Residual square error = 22.97

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?

Patterns of chitobiase-production rates and zooplankton biomass



Rank correlations VS median BPR:

- **Southern** = -1.0, p <0.001*
- **Ctenophores** = -0.9, p <0.05*

1. Temporal patterns of southern copepod and ctenophore biomass anomaly similar to crustacean zooplankton production rates

2. Models do not capture very low rates in 2015

(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.**