Pattern-oriented advances in an individual-based model for the North Pacific krill, *Euphausia pacifica*: improving realism and framing questions for future improvements

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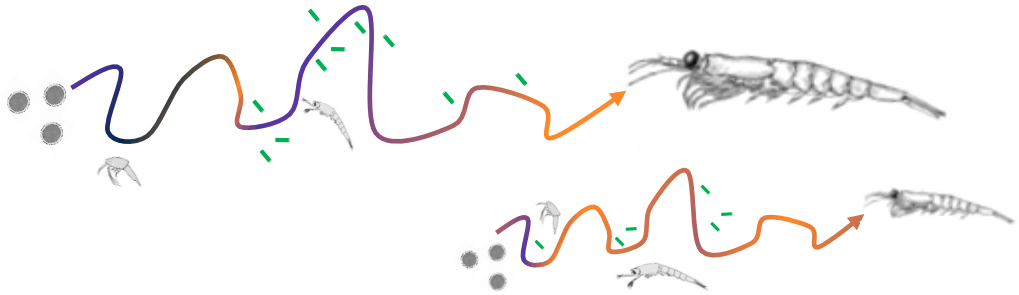
ICES-PICES International Zooplankton Production Symposium

18 March 2024

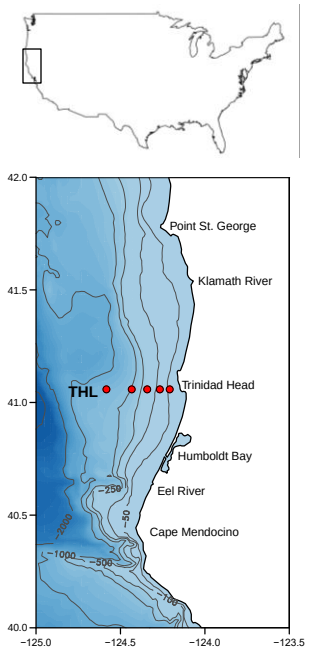


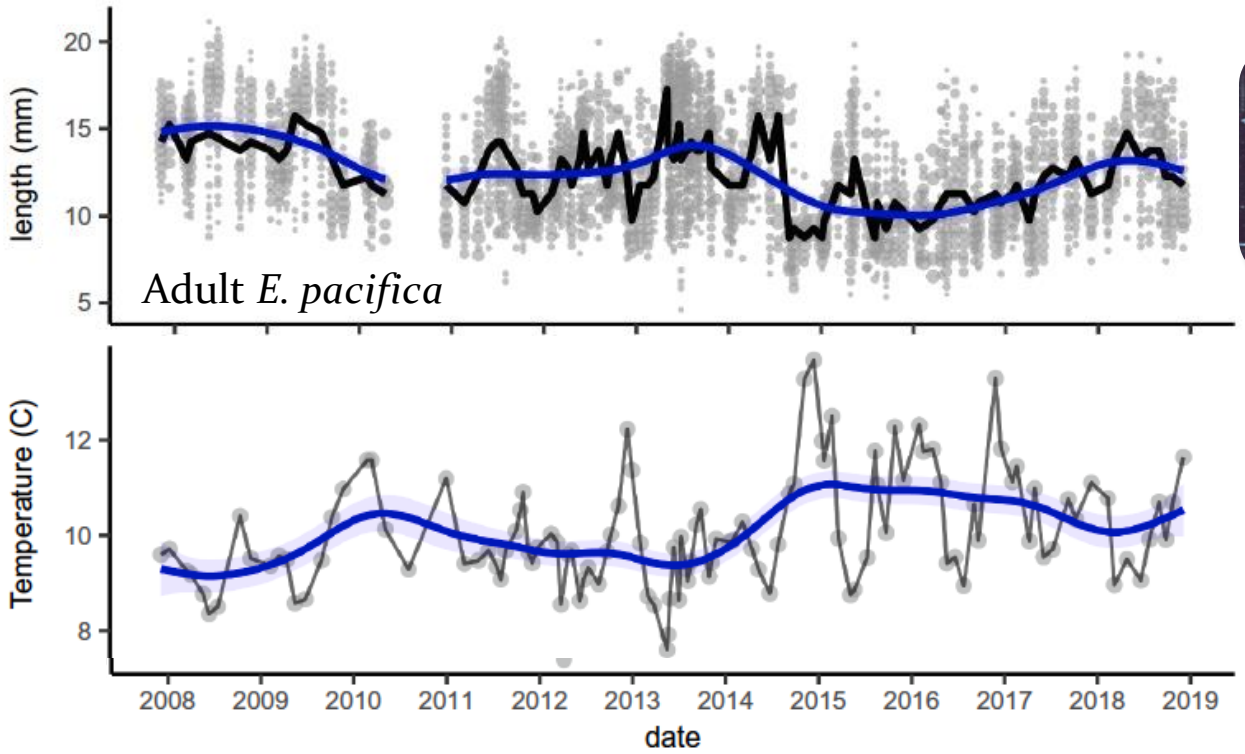
2013 ♀

2014 ♀

Thanks to funding sources!
NOAA's SWFSC via CIMEAS
Malcolm Oliphant Scholarship

Motivation for IBM





2013 ♀

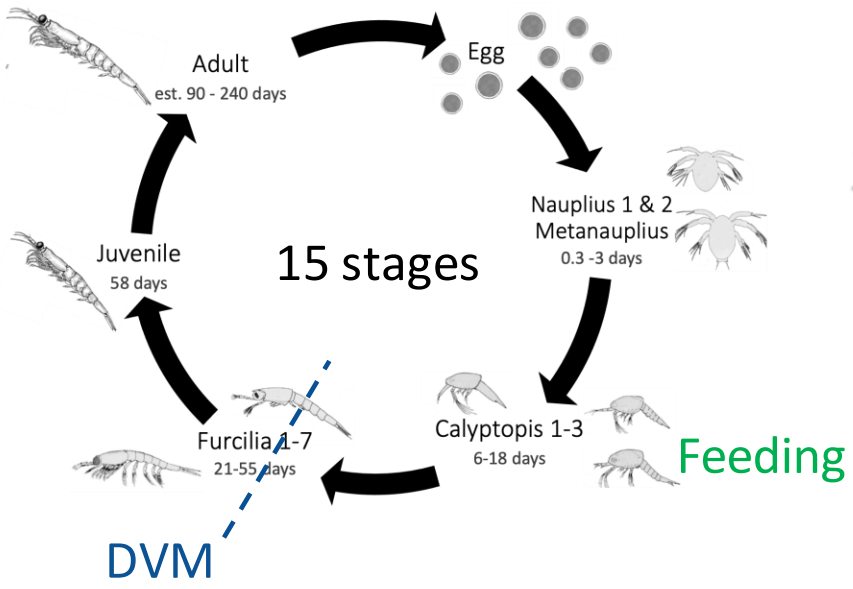
2014 ♀

Robertson & Bjorkstedt (2020)
j.pocean.2020.102412

Goal: Develop IBM to better capture growth and size variability based on observations off northern California

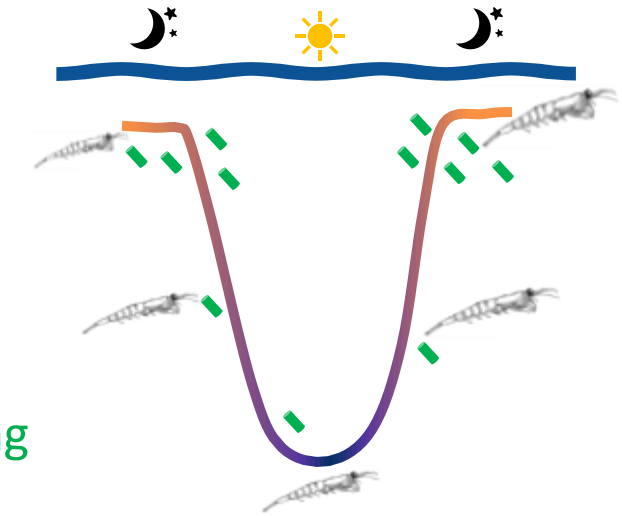
Life Cycle & Model Structure

E. pacifica



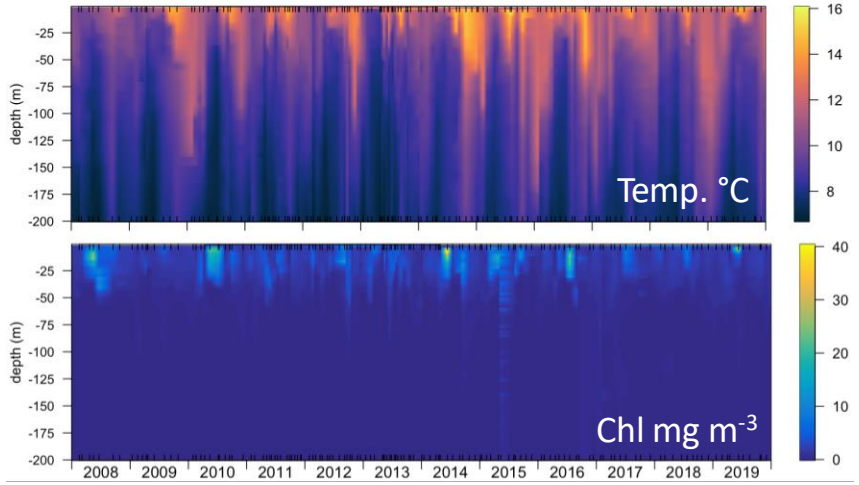
- 15 life history stages
- Currency = carbon

DVM



- Realistic DVM
- Food ≈ [Chlorophyll a]

Environment

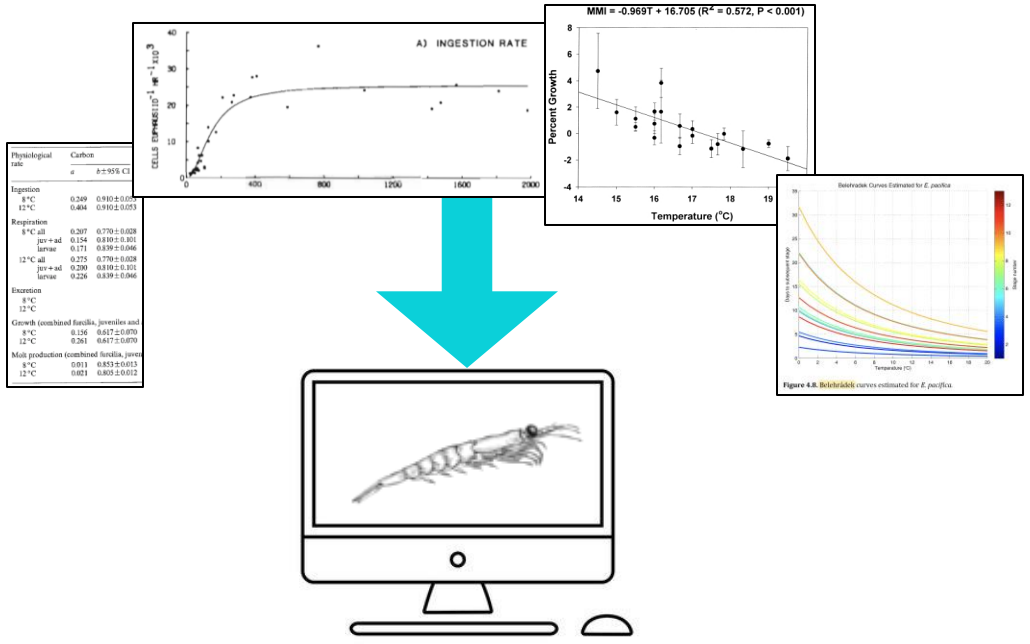


- Driven by environment off northern CA

Aligning Model with Observations

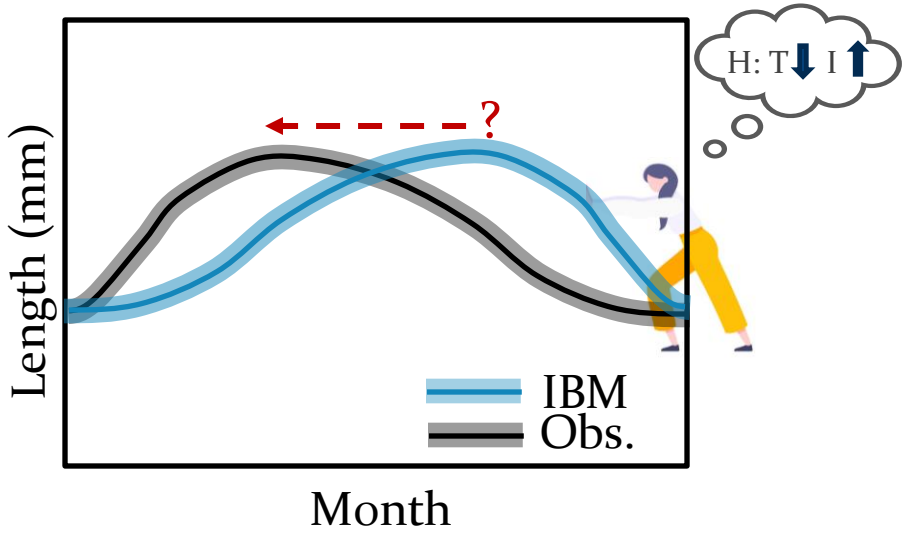
Model development has two phases:

Phase I: Make submodels more realistic based on existing literature



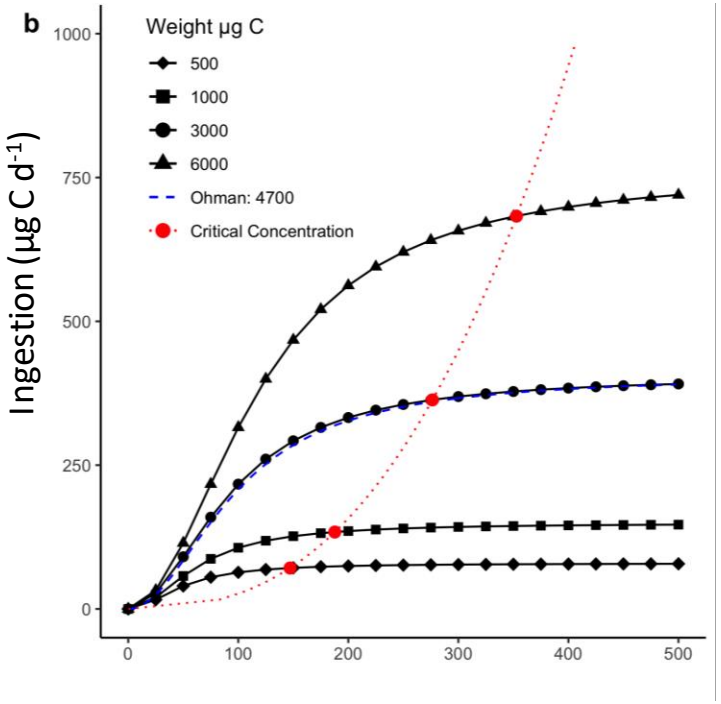
Phase II: Tune to seasonal dynamics

- Pattern oriented modeling (Grimm et al., 2005)
- Phenomenological submodels (hypotheses)



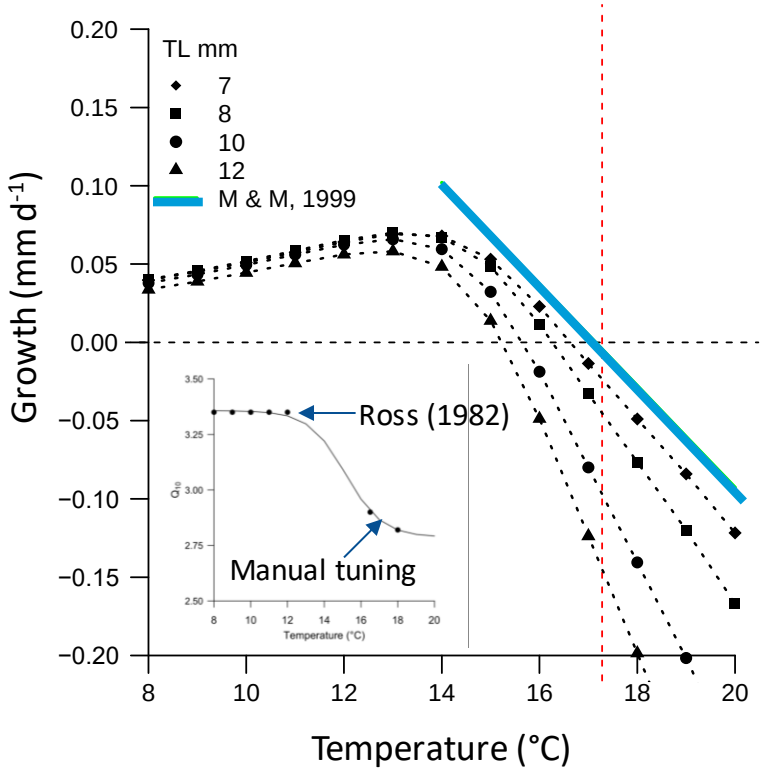
Phase I: Making submodels more realistic

1. Ingestion



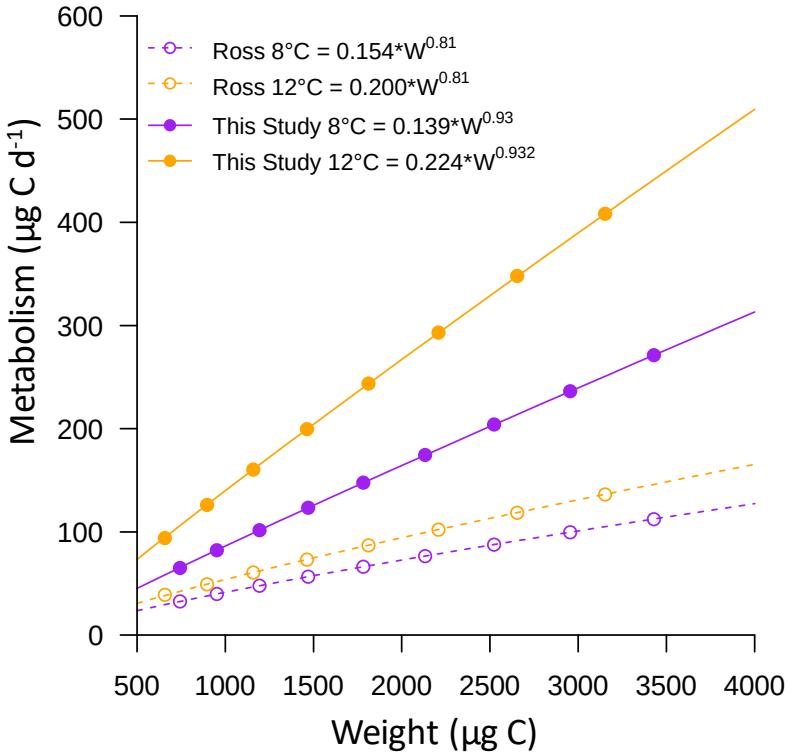
Ingestion function accounts for food density, body weight, and temperature

2. Growth (via Q_{10} ingestion)



Growth matches previous IBMs up to ~12°C, then juvenile & adult dynamics are consistent with Marinovic and Mangel (1999).

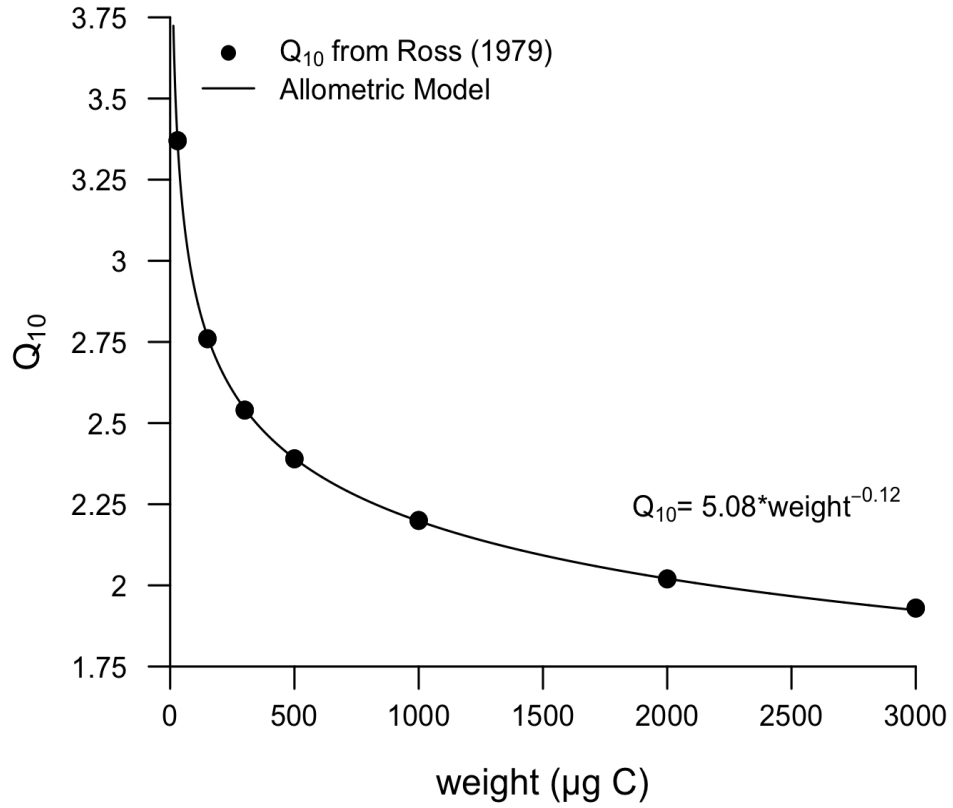
3. Metabolism



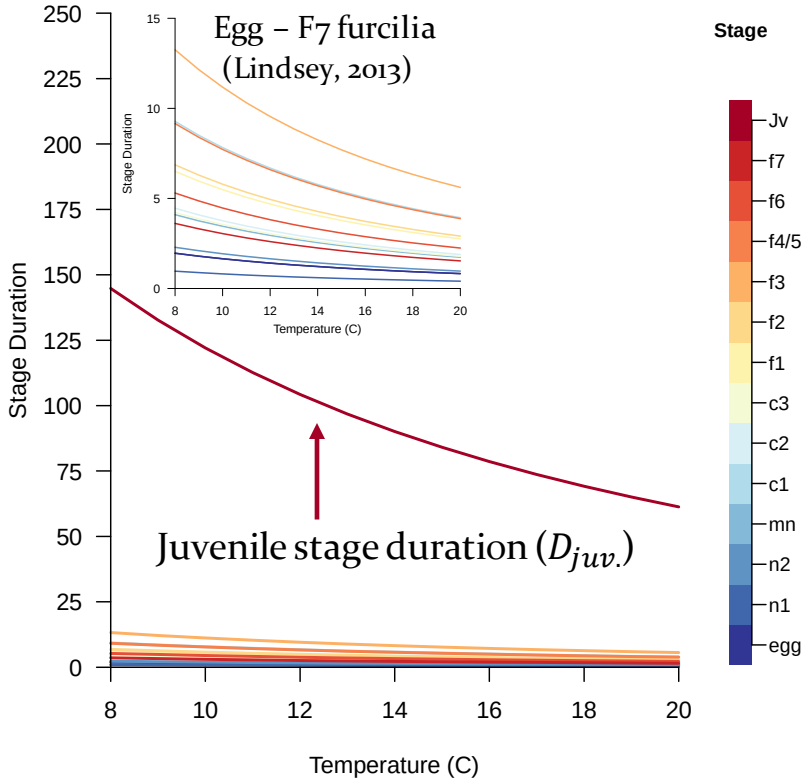
As percent of assimilated carbon: 62-81% (Consistent with Lasker, 1966)

Phase I: Making submodels more realistic

4. Molting



5. Age-at-maturity $D_{juv.} = a_{juv.}(T + B)^{c}$

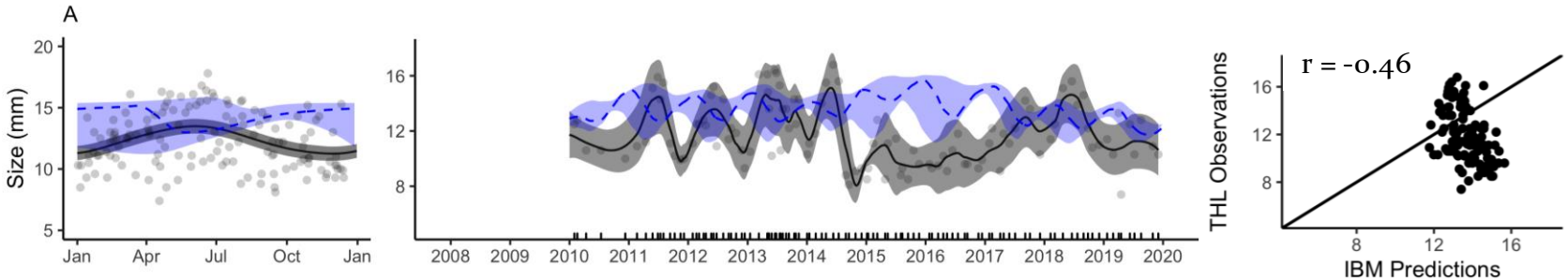


Age-at-maturity consistent with field-based observations: 90 – 240 days
(Harvey et al., 2010, Shaw et al., 2021)

Phase I: Results & Diagnosis

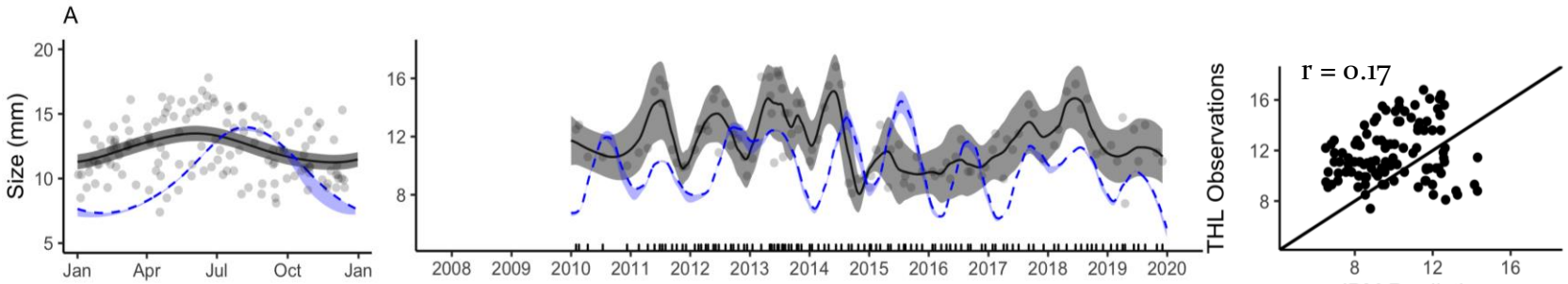
Base Model (Based on Dorman et al., 2015)

Predictions **not** in phase with observations



Phase I

Predictions in phase with observations!



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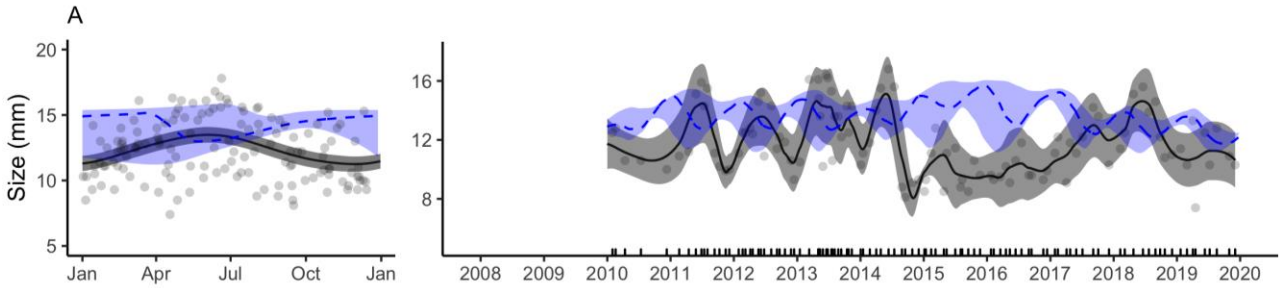

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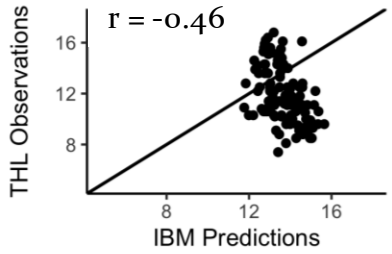

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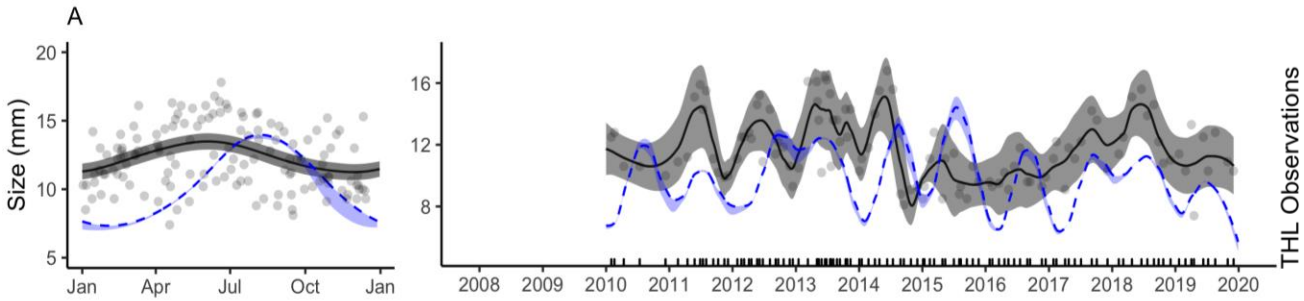
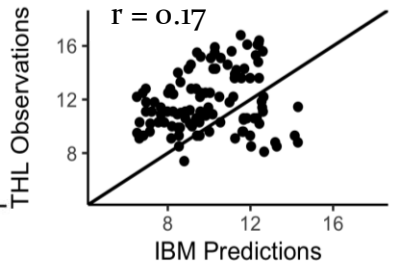
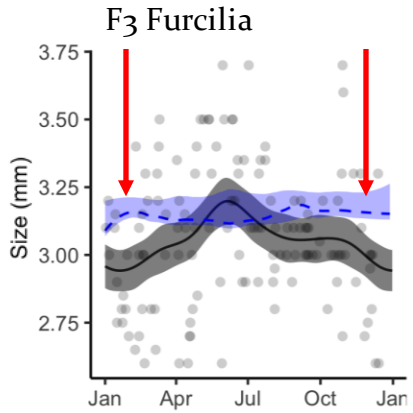


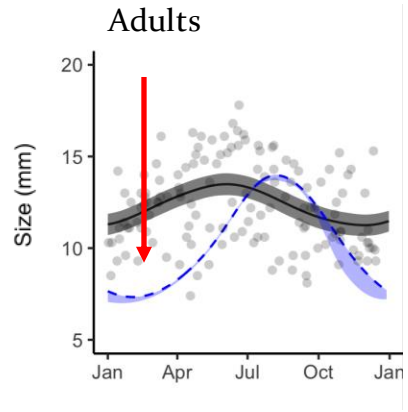
Predictions in phase with observations!



IBM THL Data THL GAM

Discrepancies remain…



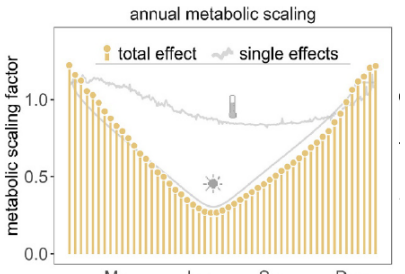


…at this point, no experimental data to inform physiology…

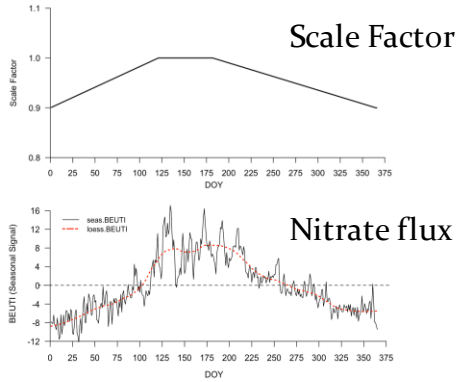
Phase II: Phenomenological Tuning

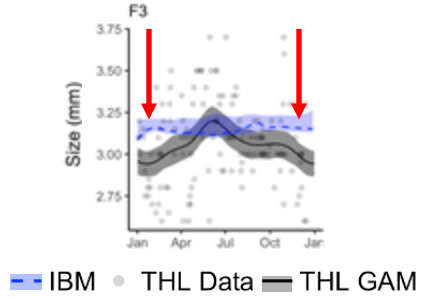
A: Scaling function (DOY) to address discrepancy in furcilia size

H: energetics are seasonally variable (e.g., food quality, quiescence)



Seasonal scaling of energetics
(Bahlburg et al., 2021)

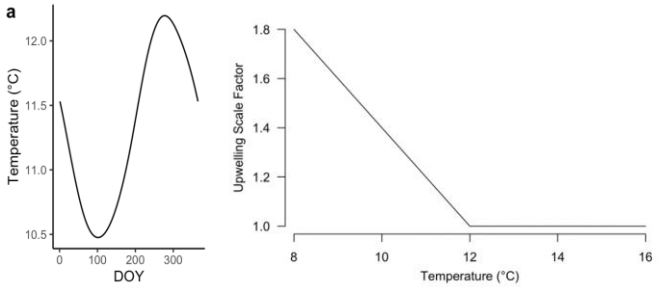


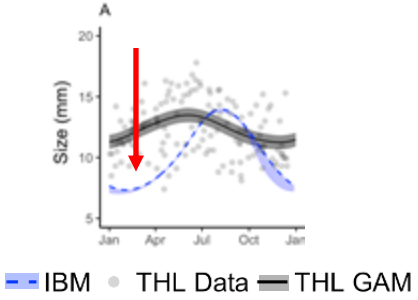


B: Scaling function (temperature) to address discrepancy in adult size

H: enhanced assimilation during upwelling

(temperature as proxy for productive upwelling season)





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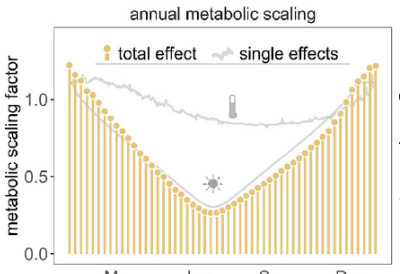

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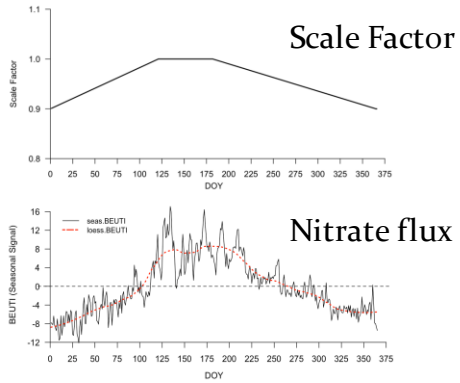

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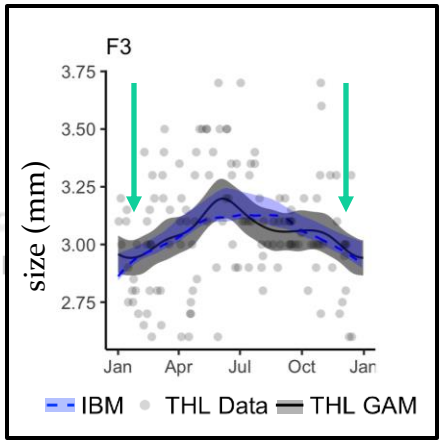

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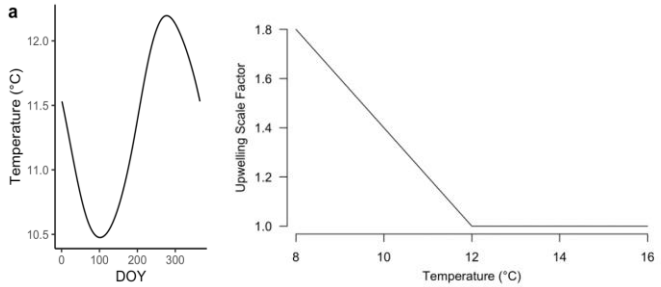

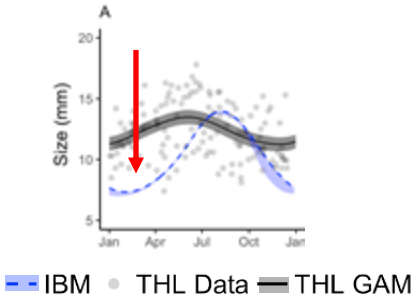

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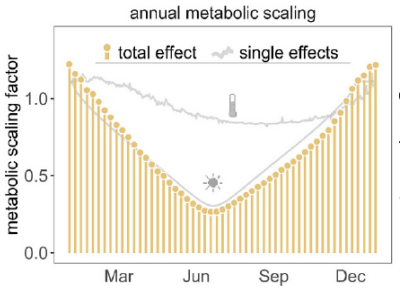

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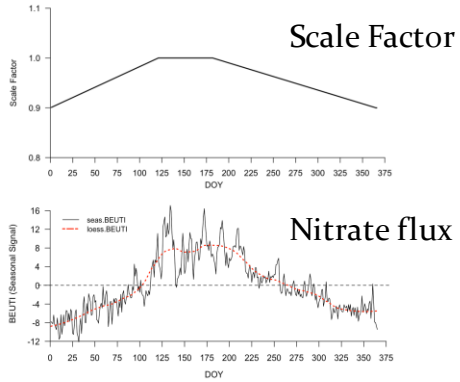

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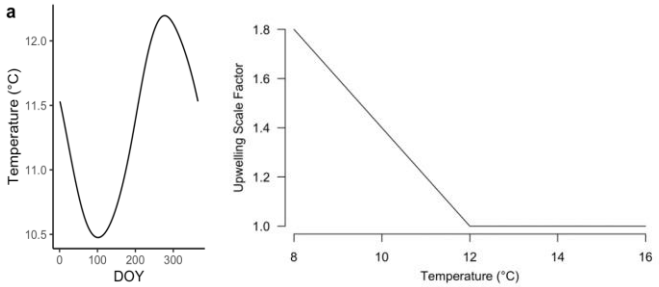
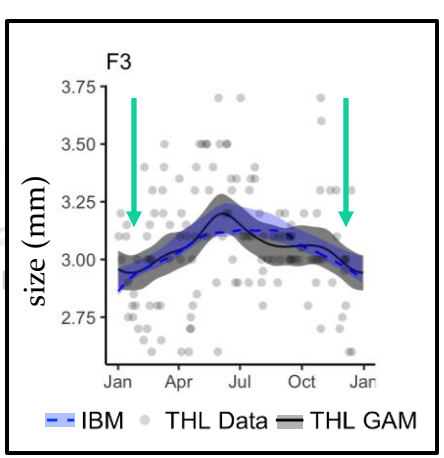
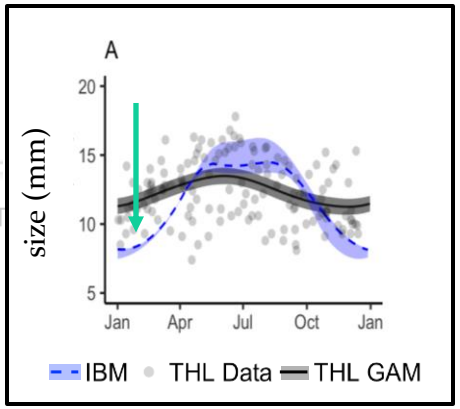


Phase II



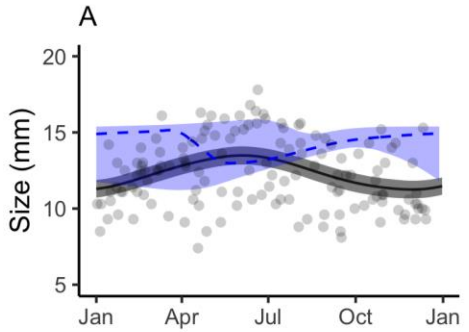


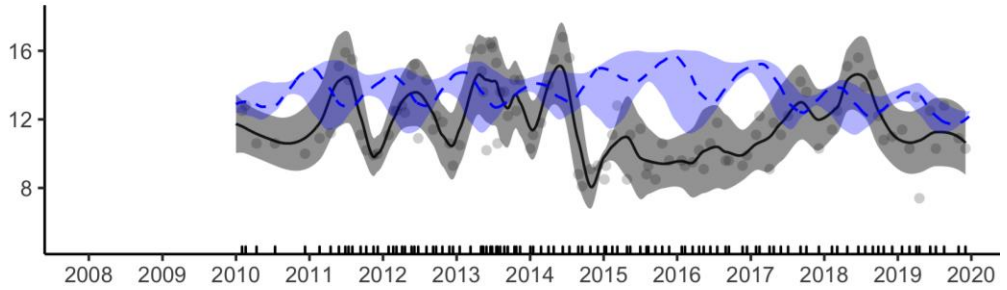
Phase II: Results

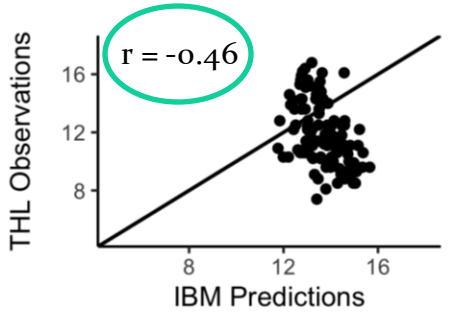
Base Model

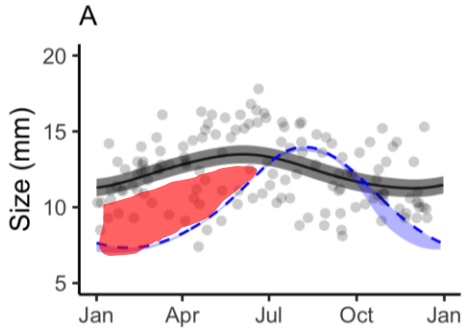
Phase I

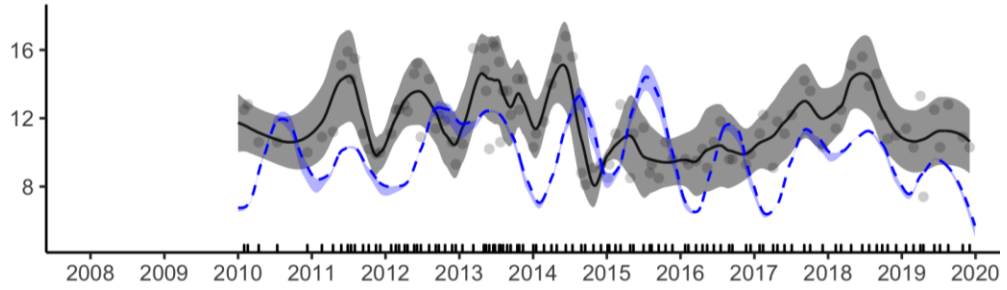
Phase II

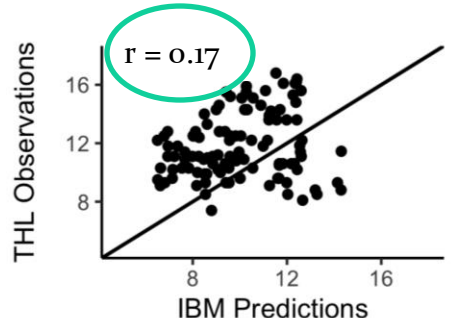


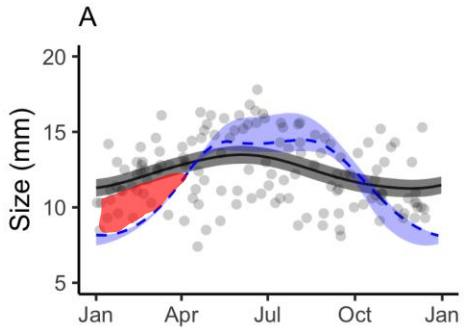


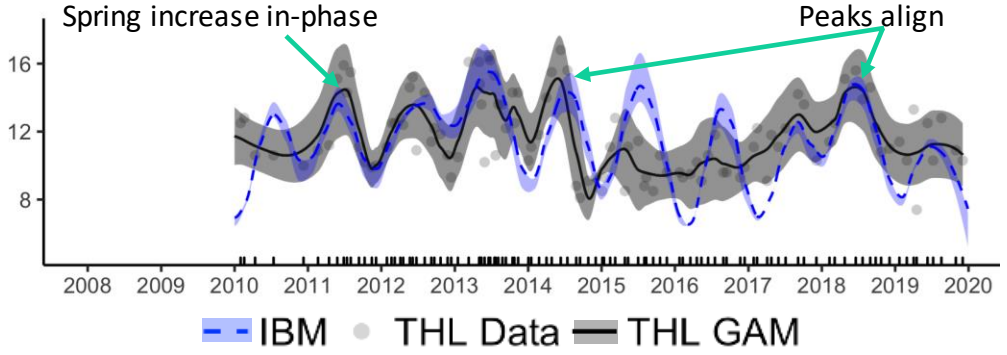


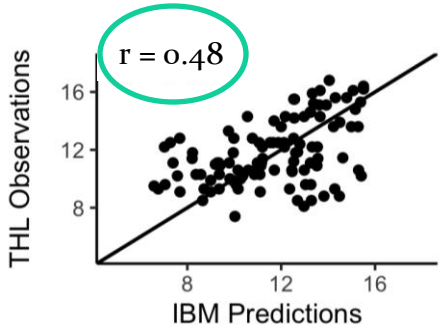




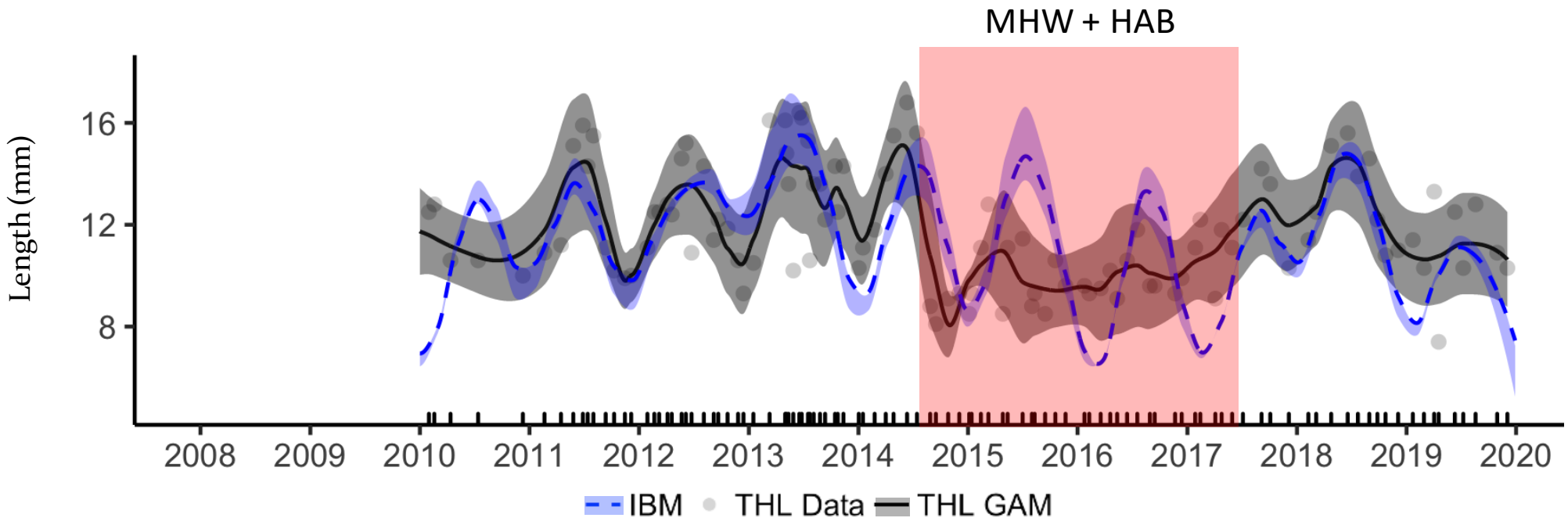








Marine heatwave + HAB



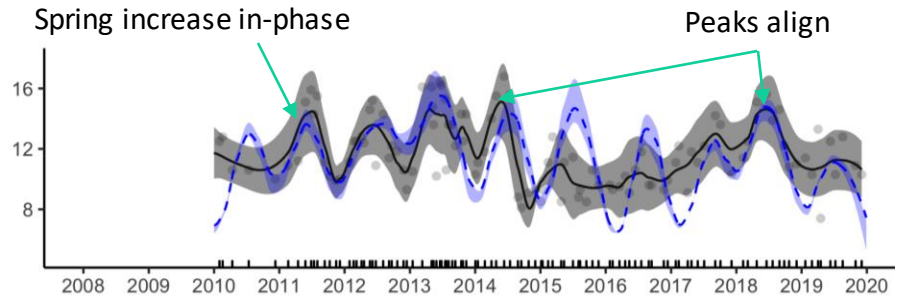
Discrepancies coincide with major warming event & HAB

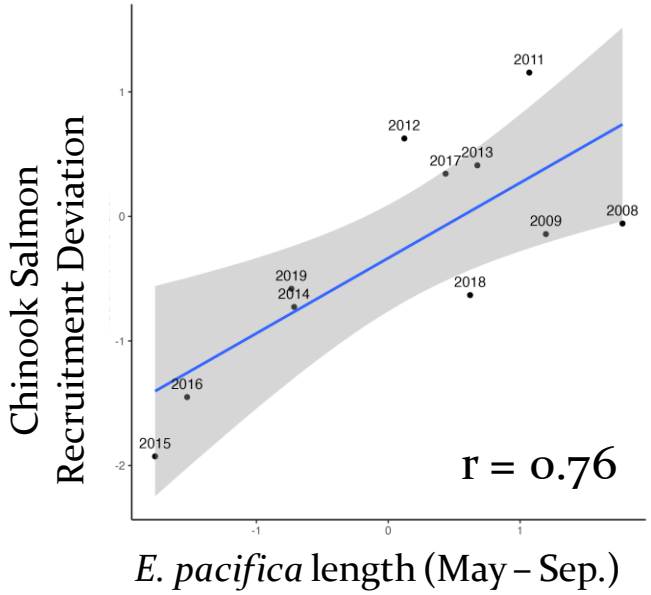
- Effects of unprecedented harmful algal bloom (McCabe et al., 2016)
  - Domoic acid suppresses ingestion (Bargu et al., 2006)
- Effects of MHW on quality of food (Kim et al., 2024)

Summary & Conclusions

- Improved realism by incorporating empirical observations
- POM yielded further improvements
- Model outputs compare favorably to other krill data sets

Strengthens foundation for IBM to serve as tool for broader examination of ecosystem dynamics





"A model, once it is running reliably…is like a laboratory waiting to be used."
- A. Starfield, K. Smith, and A. Bleloch