Predicting copepod dormancy timing in response to climate change

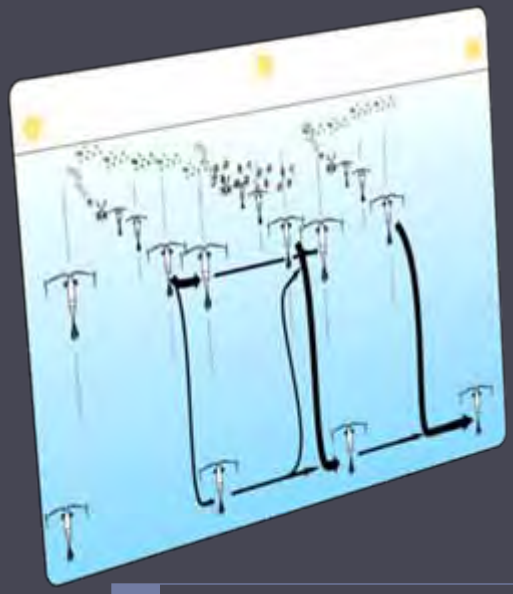
Pierson, Runge, Head, Plourde, Johnson, Leising, Maps, Kimmel, Pershing, Gentleman

The original plan

- Describe the *NEW* analysis of dormancy timing from all available time series data
- Show comparisons with model data to highlight model ability to predict dormancy timing
- Show scenario tests with the model to show timing changes with warming

The New Plan

- Discuss life history metrics, their usefulness and importance to compare between and within species
  - Dormancy
  - Growth
- Predicting changes in life histories, specifically dormancy
- What's Next

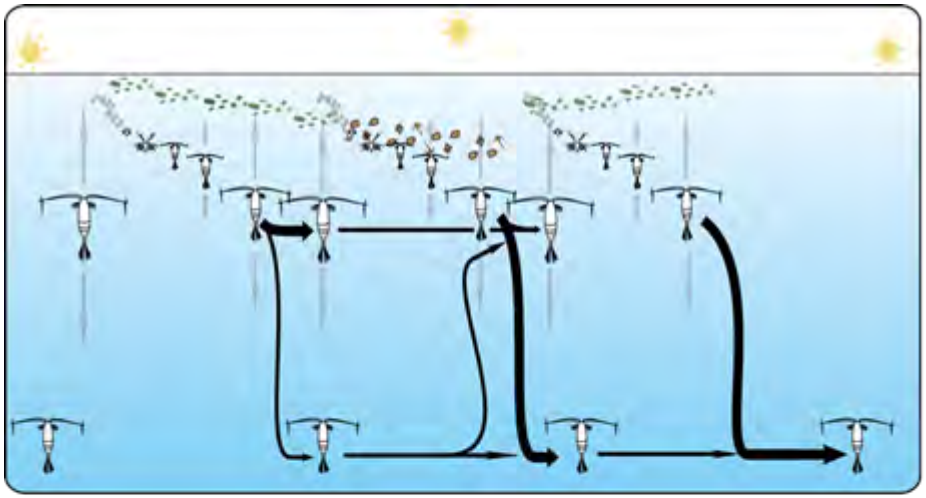


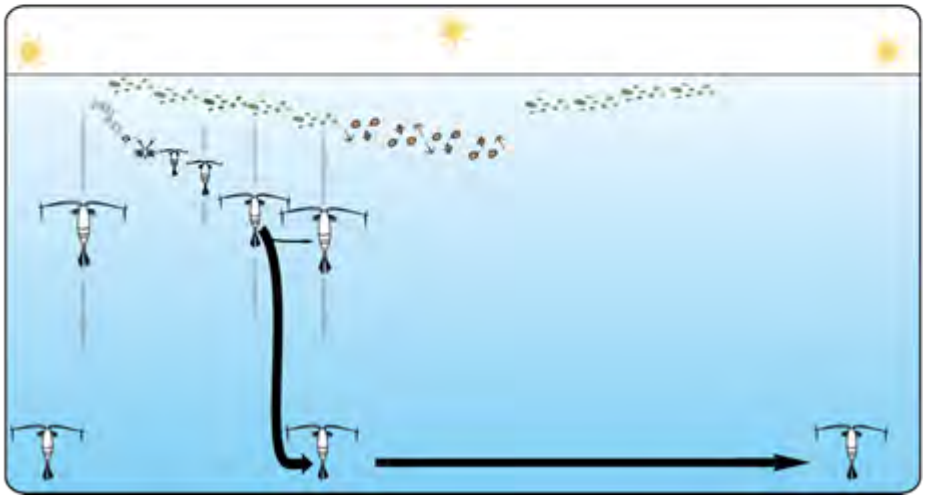
Life history metrics

"Birth, School, Work, Death"

Birth, School, Work, Death, *The Godfathers*, 1988

Calanus life cycle plasticity may lead to varied lipid utilization strategies

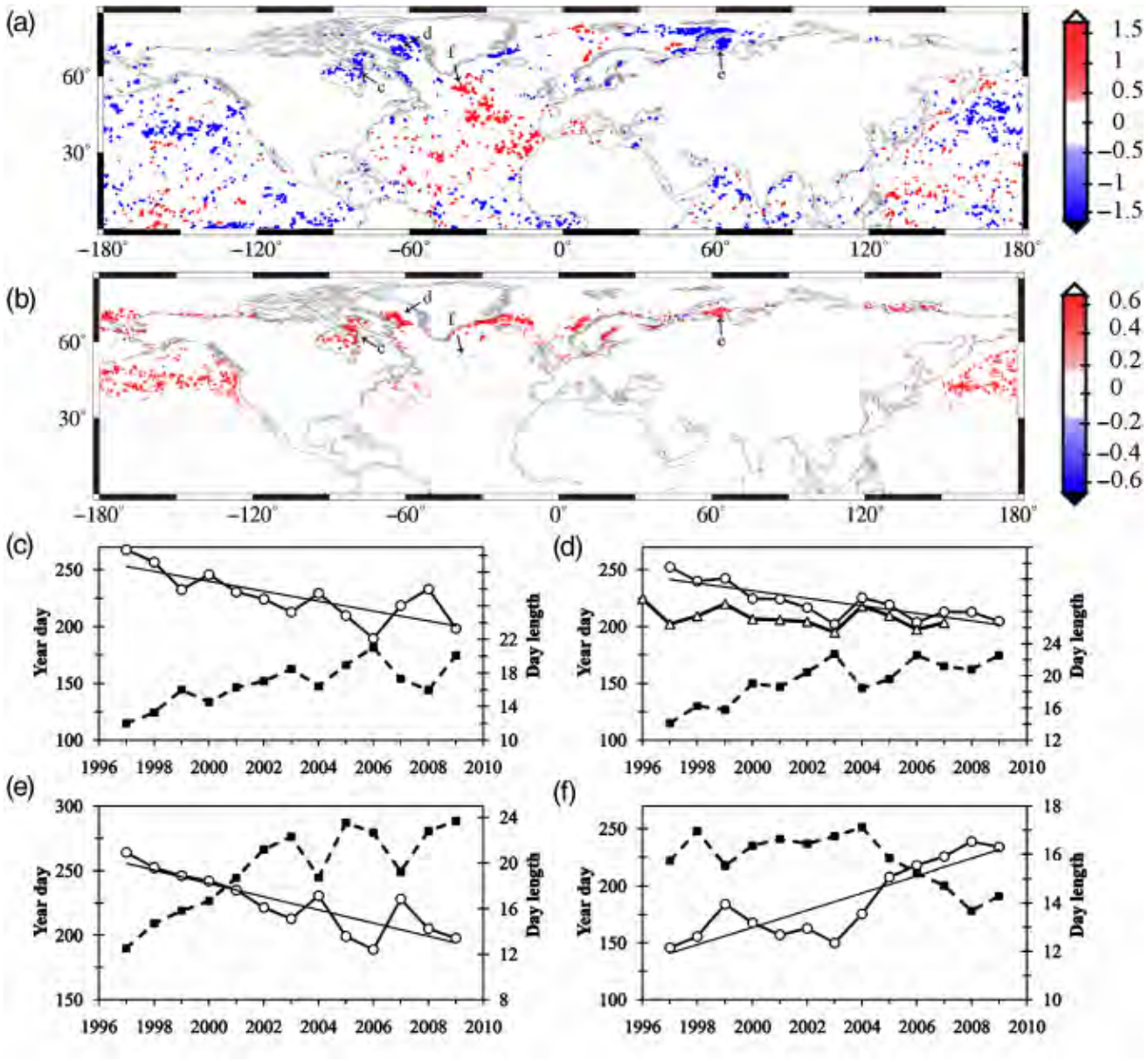




Various strategies may be found in one species:

e.g. *Calanus marshallae*

- 1 generation year^{-1}
  Dabob Bay
- 2-3 generations year^{-1}
  Oregon Shelf, Bering Sea



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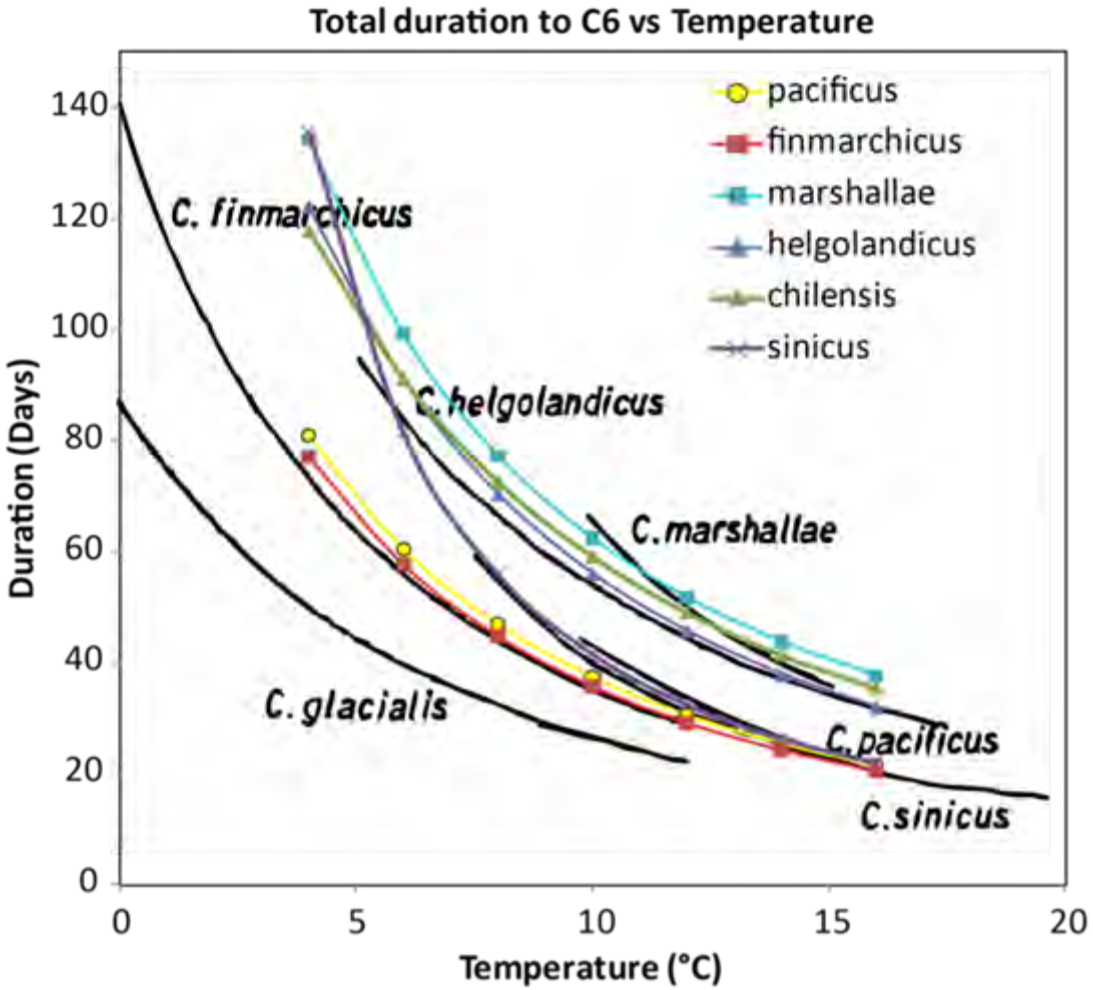
Kahru et al. 2011

Life history metrics to consider for comparisons and prediction

- Development Rate
  - Generation Time
- Growth Rate
- Adult Size
- Fecundity
  - Per capita
  - Cumulative
- Dormancy Timing
  - Initiation
  - Termination
- Reproductive Period

Development time to C6 varies by species



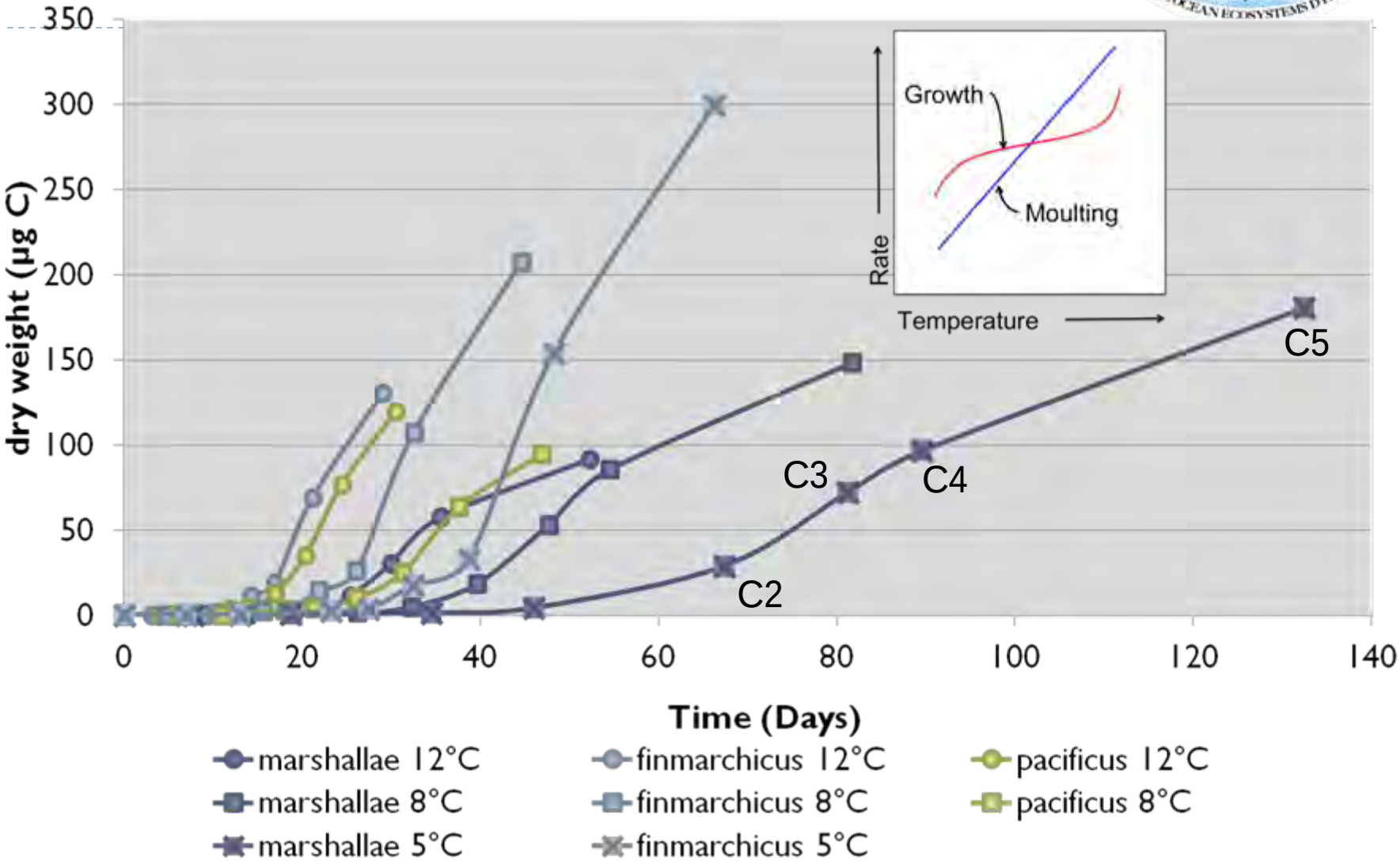
$$D_j(T)=\alpha_j(T+T_d)^{\beta}$$

β = -2.05

= -1.44 (*C. sinicus*)

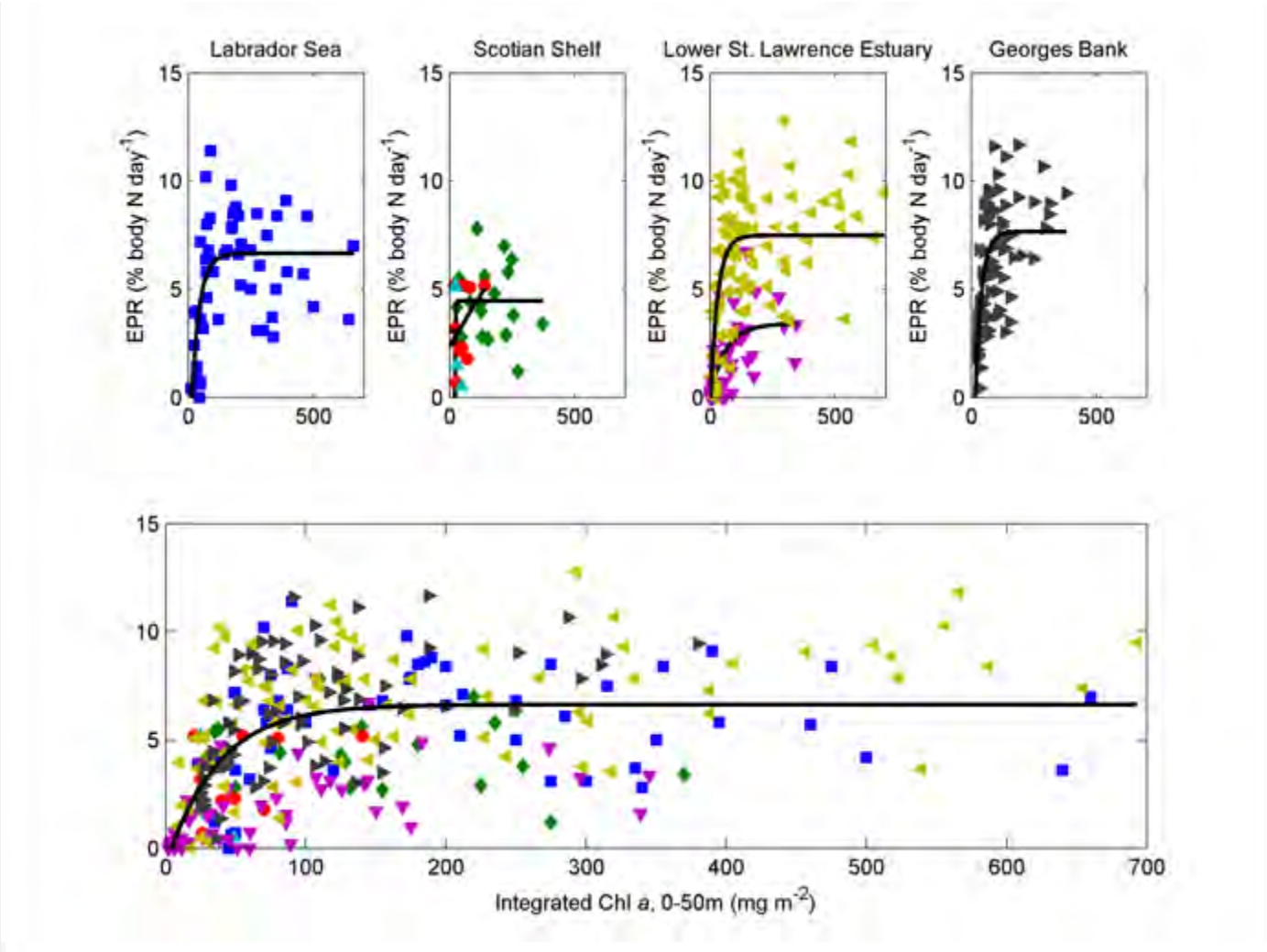
Uye 1988 and others

Resulting Size vs. Time (by Stage)

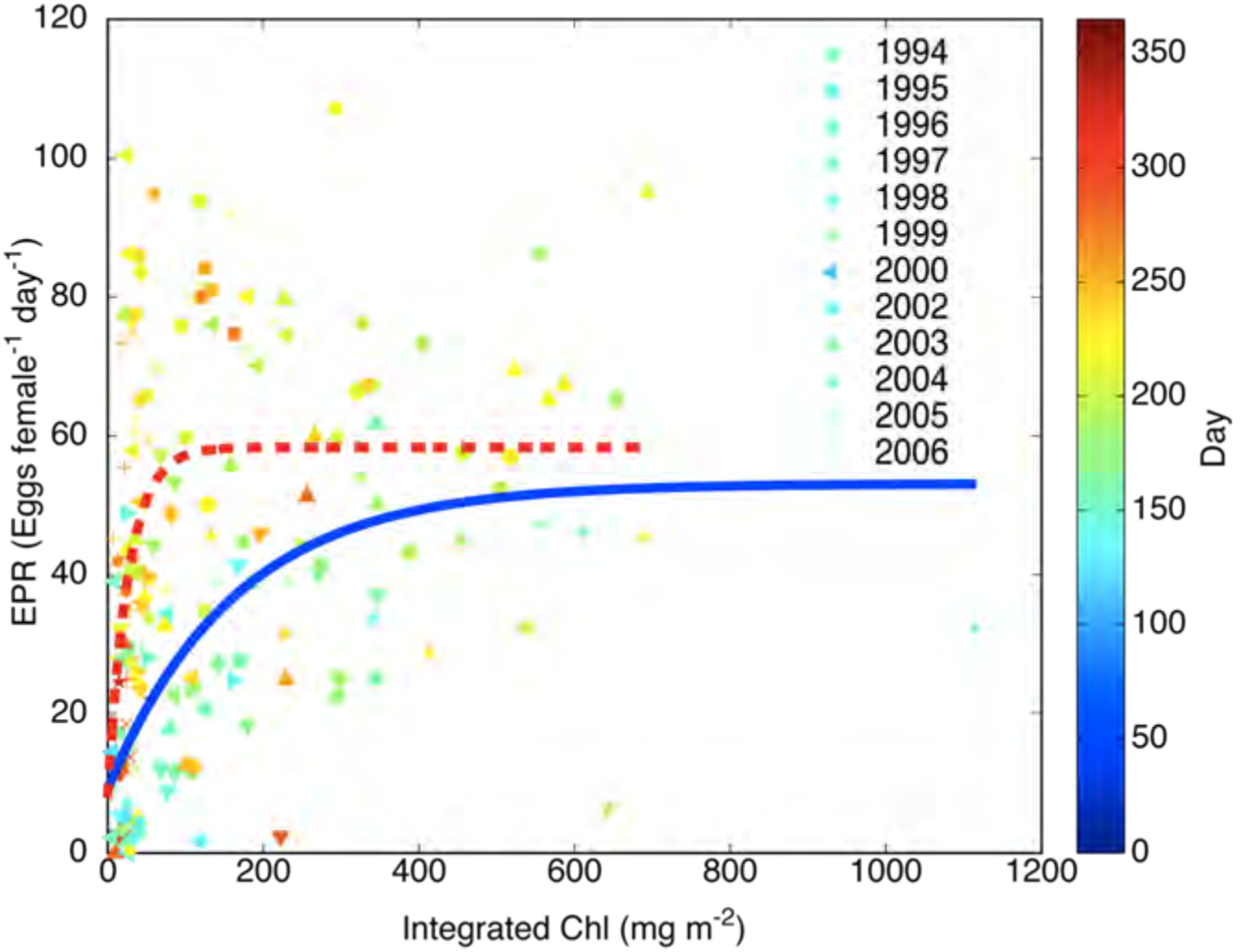


Leising unpublished, Johnson et al. 1977

Spatial and temporal patterns in Egg Production Rate



Spatial and temporal patterns in Egg Production Rate



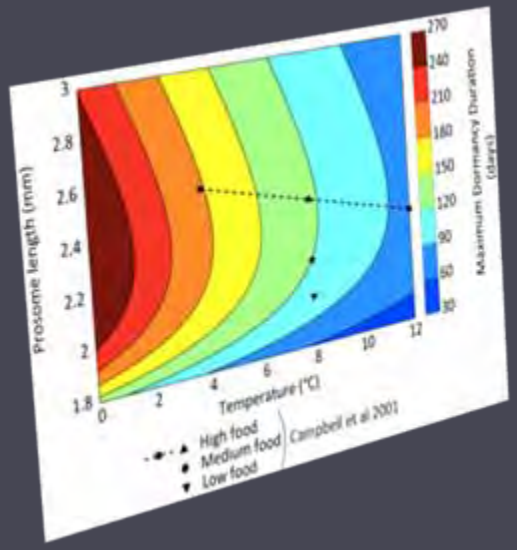
Growth period (Plourde) differs from non-dormant period

	% of Maximum Population EPR											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
GoM	0.57	0.71	1.00	0.72	0.29	0.53	0.36	0.23	0.09	0.09	0.02	0.11
SS	0.15	0.74	0.85	1.00	0.56	0.31	0.38	0.17	0.22	0.07	0.04	0.07
GSL	0.02	0.05	0.13	0.87	1.00	0.55	0.66	0.22	0.17	0.06	0.02	0.02
NL	0.04	0.11	0.47	0.62	1.00	0.12	0.33	0.09	0.18	0.07	0.03	0.05
NorSea	0.00	0.03	0.15	1.00	0.68	0.33	0.13	0.04	0.09	0.03	0.01	0.00
	N_{DT}>30	N_{DT}>30	N_{DT}>30									N_{DT}>30

Dormancy End (Johnson et al. 2008)

Dormancy Start (Johnson et al. 2008)

Plourde “Growth Period” = Pop EPR_{max} > 0.15



Predicting changes in life histories
Specifically: Dormancy timing

"No sleep till Brooklyn"

Licensed to Ill, *Beastie Boys*, 1986

What do we know about dormancy?

Direct Controls?

- ~~Photoperiod~~
- ~~Temperature~~
- ~~Food~~
-

Drivers

- Lipid volume
- Temperature controlled metabolic rates
- Mortality pressure?

Can we predict how *Calanus* dormancy might change with a warming climate?

Empirical Models

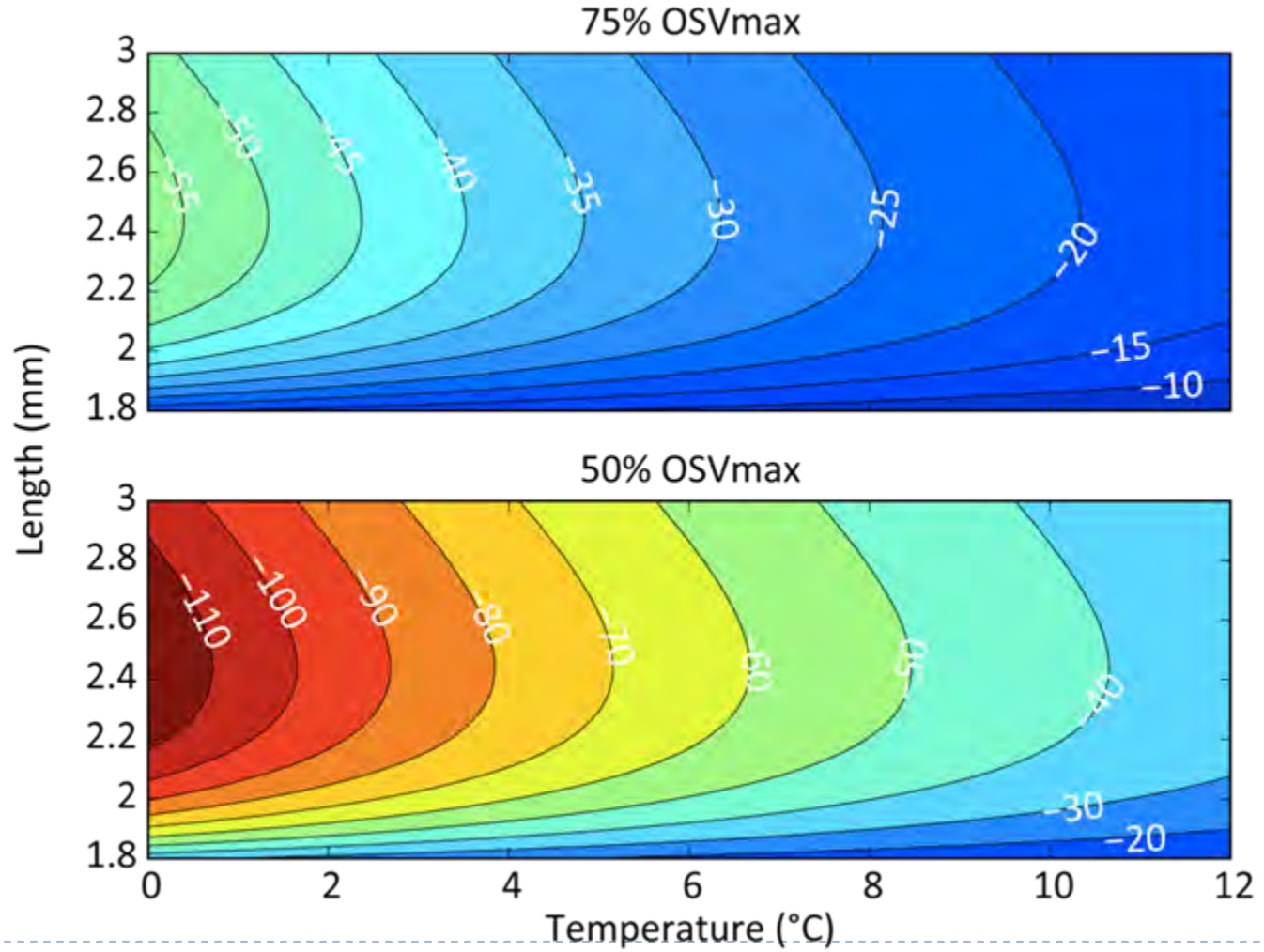
- Dormancy Duration
- Temperature and size dependent lipid utilization (Saumweber et al. 2006)

Numerical Models

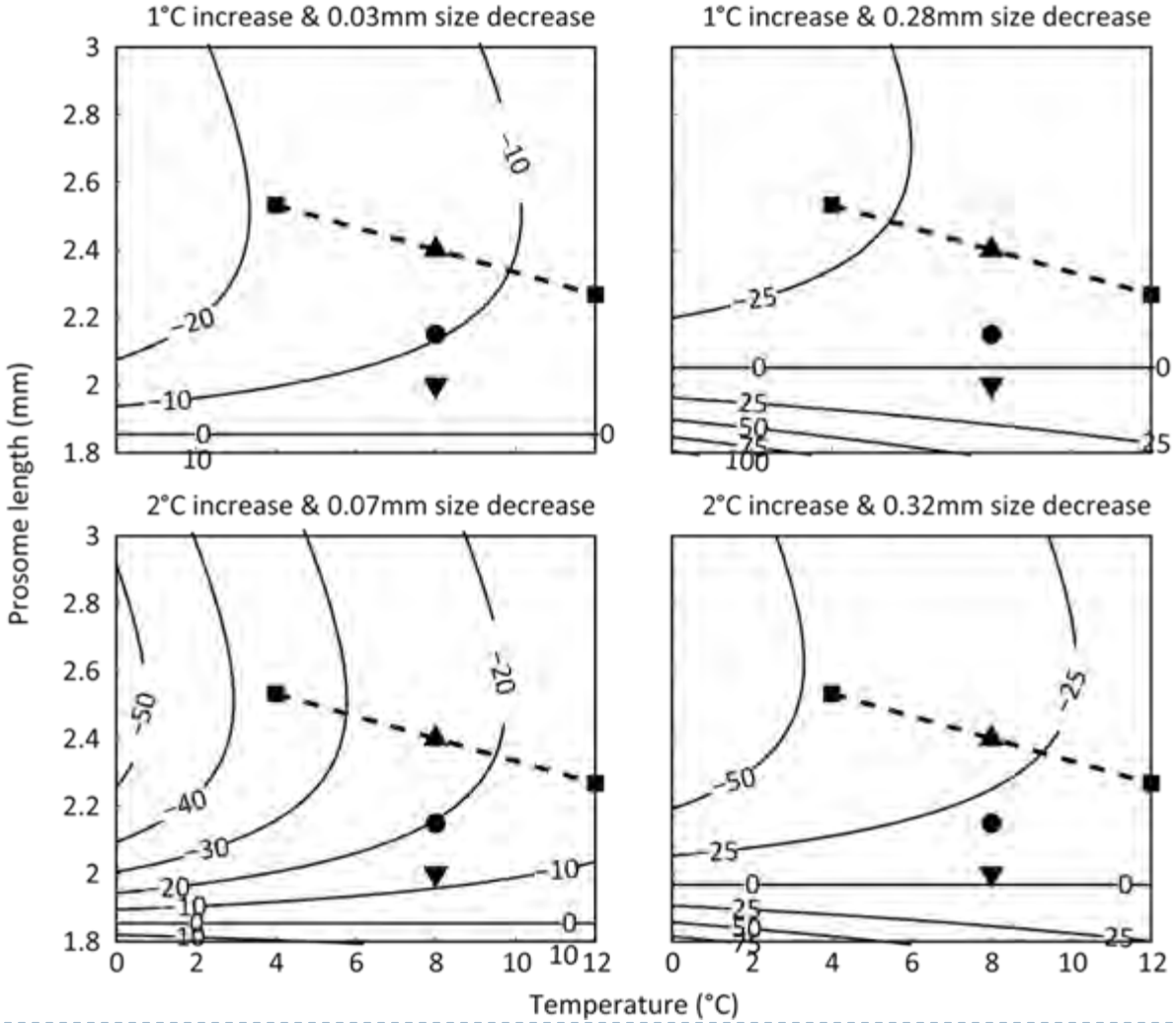
- Size at Maturity and Dormancy Entry
- Temperature and food dependent growth and development
- Lipid & Dormancy parameters using the Lipid Accumulation Window (LAW) hypothesis

cf. Johnson et al 2008

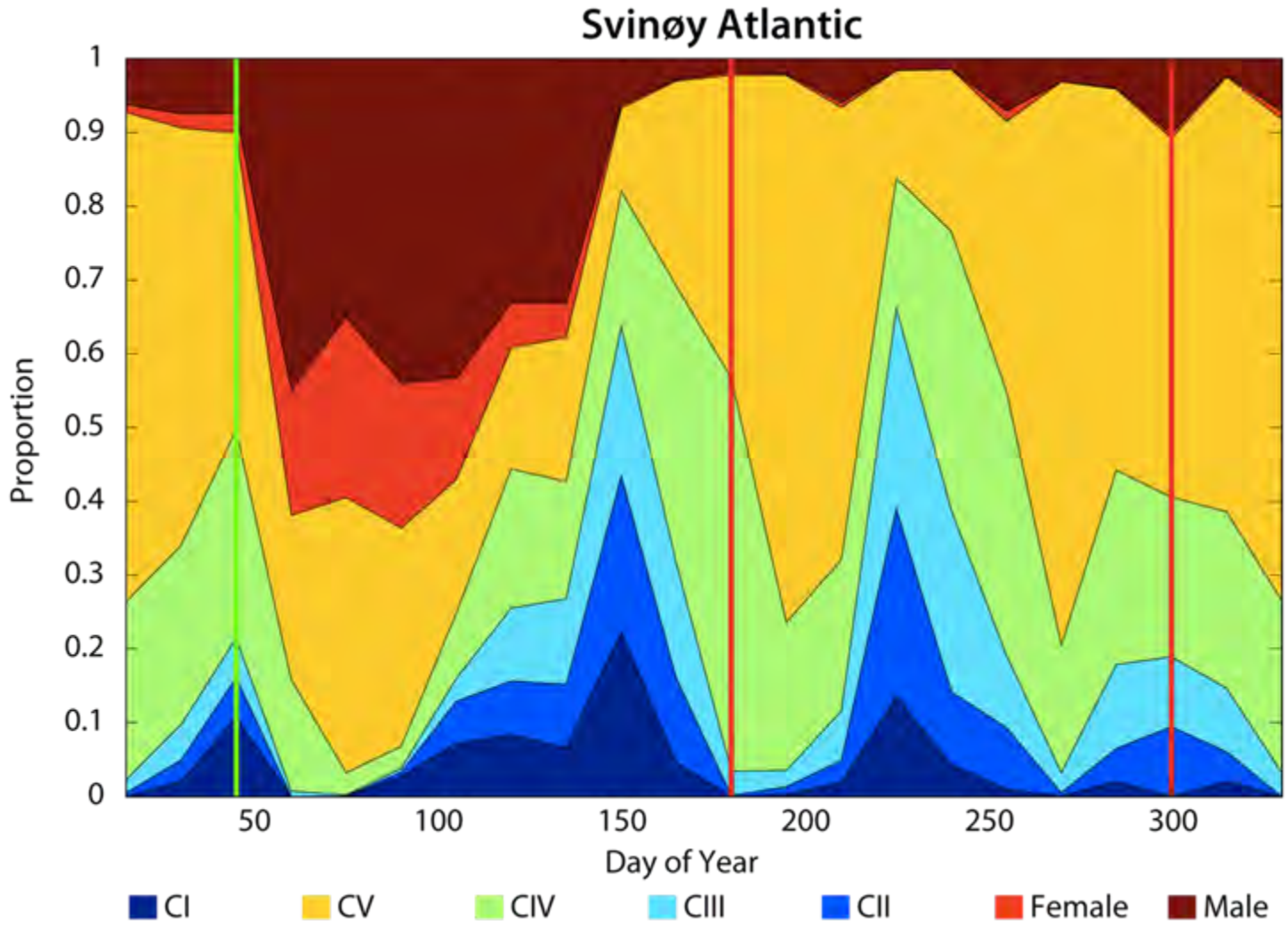
Dormancy timing changes: total lipid accumulation



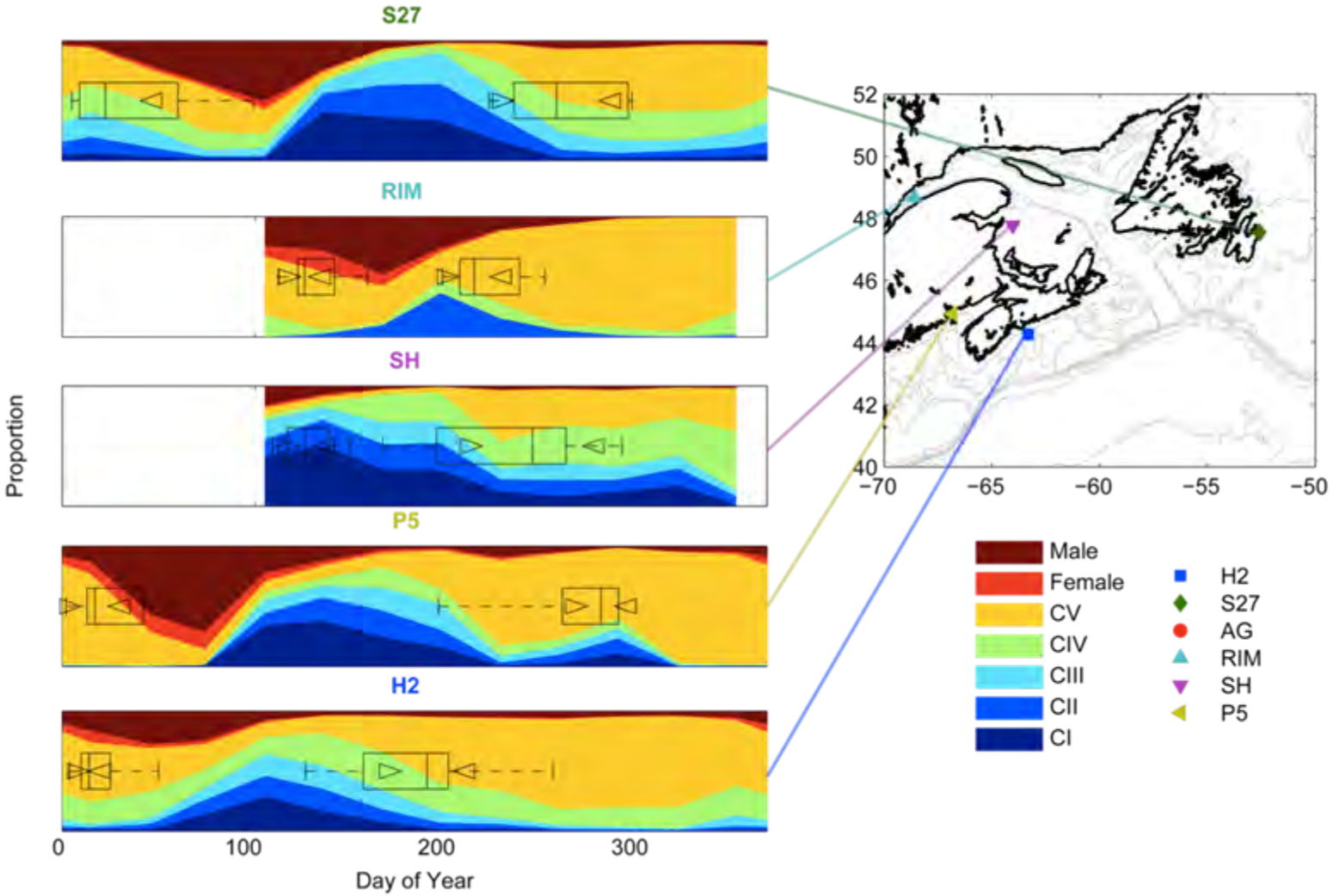
Dormancy duration (days) changes with temperature increase and size decrease



Demographics and dormancy timing off Iceland

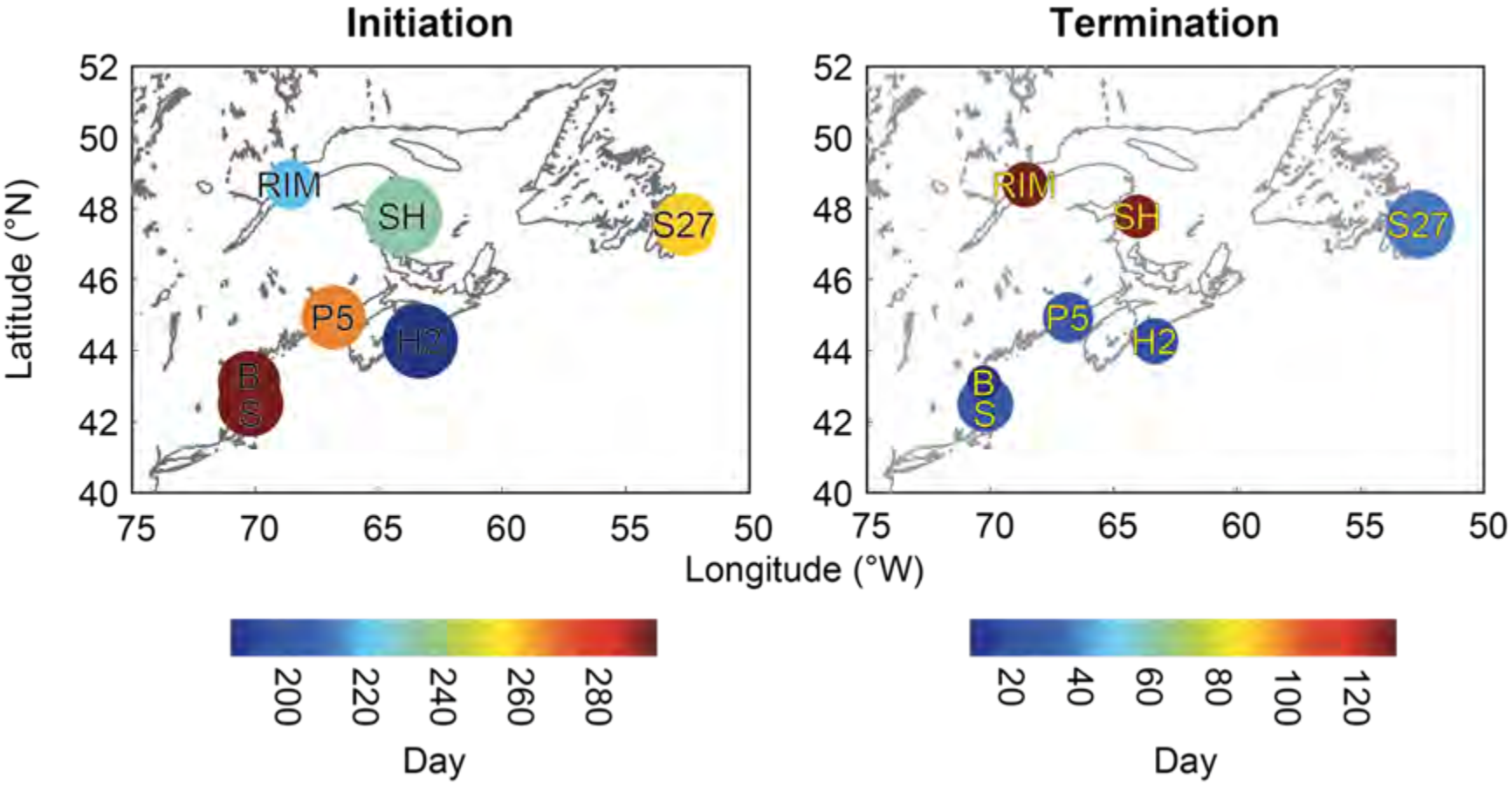


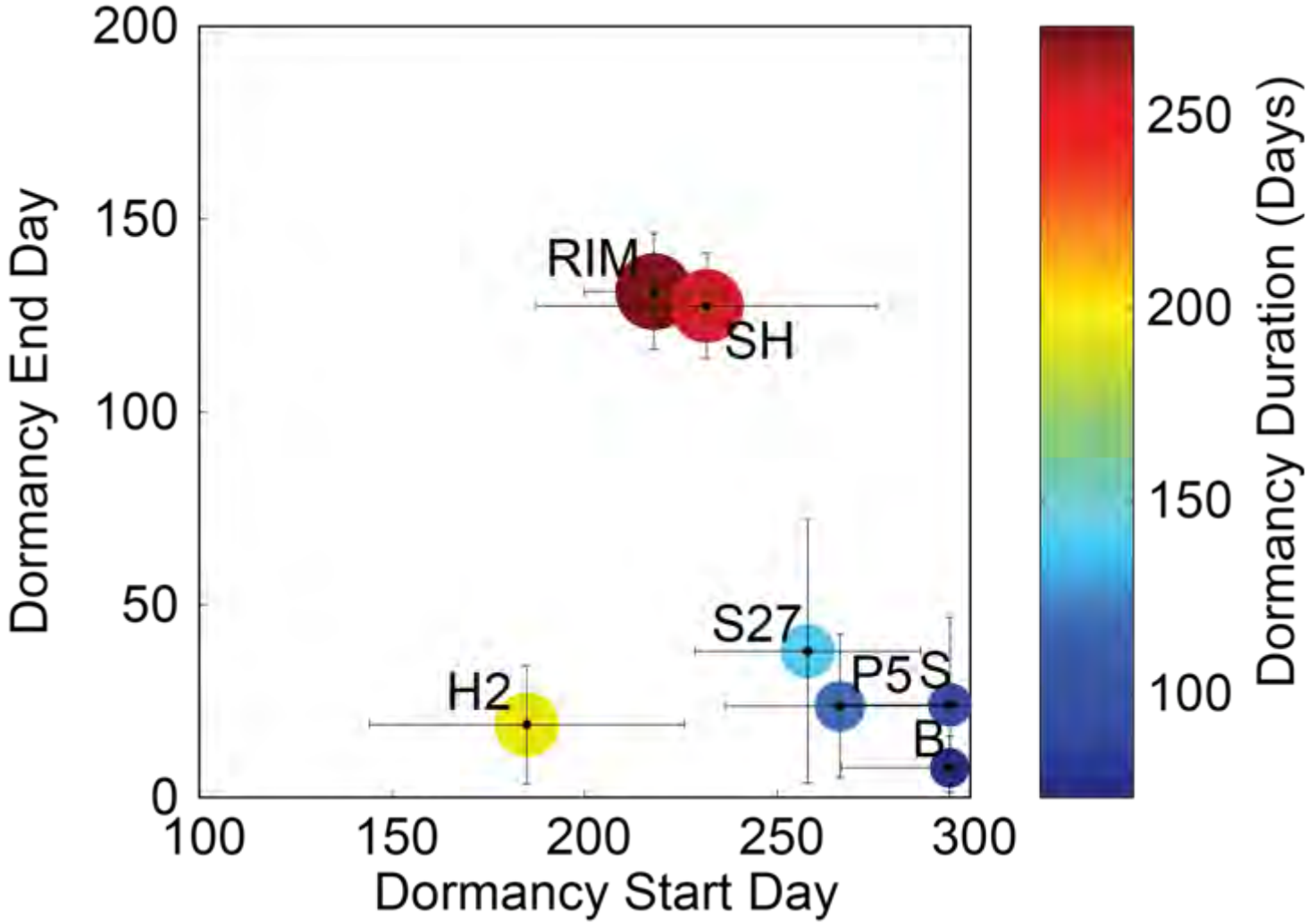
AZMP Time Series Data

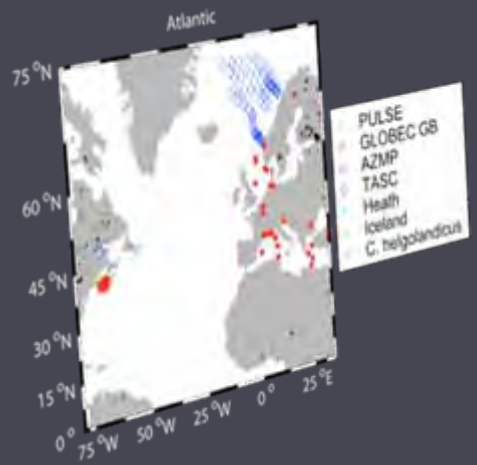


- *cf.* Johnson et al. 2008 ICES JMS

Dormancy timing NOT related to more things than it is related to...




Dormancy End Day
200
150
100
50
0
100
150
200
250
300
Dormancy Start Day
RIM
SH
S27
P5S
H2
B
250
200
150
100
Dormancy Duration (Days)



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Next steps for our project

"Your time is gonna come"

Your Time is Gonna Come, *Led Zeppelin*, 1969

Runge et al. GLOBEC PRS Objective and Hypothesis

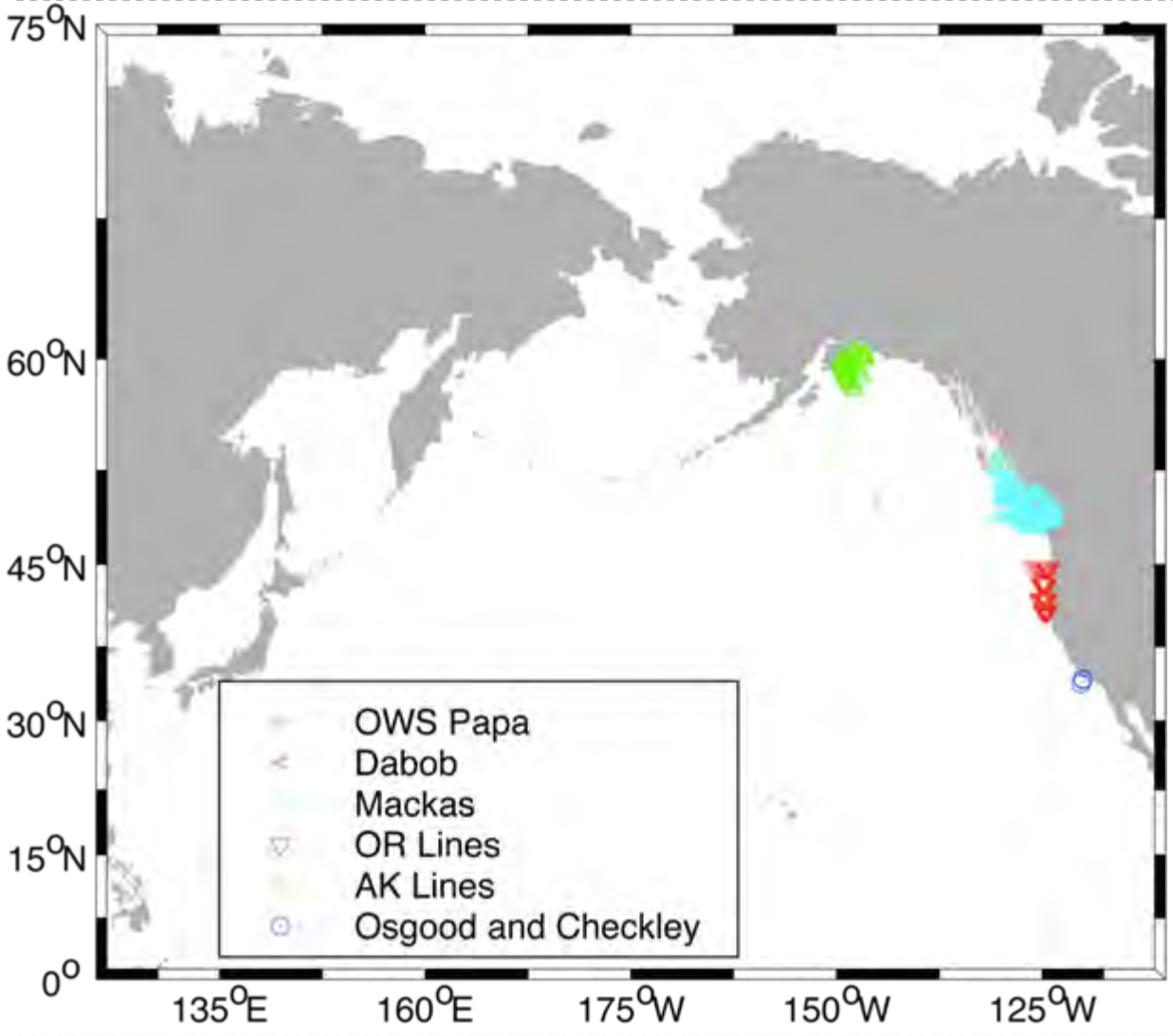
Review and synthesize knowledge for sibling species:

C. finmarchicus and C. helgolandicus in the North Atlantic

Hypothesis:

"The timing of ***entry and exit from dormancy***, as modulated by species-specific physiology and effects of climate-forced variability of food and ambient temperature on lipid accumulation, exerts an important control on population dynamics. "

Directions & Partnerships



- Few times series are long enough
- Compare between species and between basins
- T, Chl, & Stage-specific data
- *Partnerships*