

$$\frac{[E]}{[E_G] + \kappa[E]} \left( \frac{[E_G] \cdot \{ \dot{P}_{Am} \}}{[E_m]} \right)^{2/3} + \left( \frac{X_k}{X^* + X_k} \right)$$

$f \cdot V^{2/3}$  with  $f = \dots$

$\{j_{Xm}\}$

$u \cdot X$

$f \cdot V^{2/3}$  with  $f = \dots$

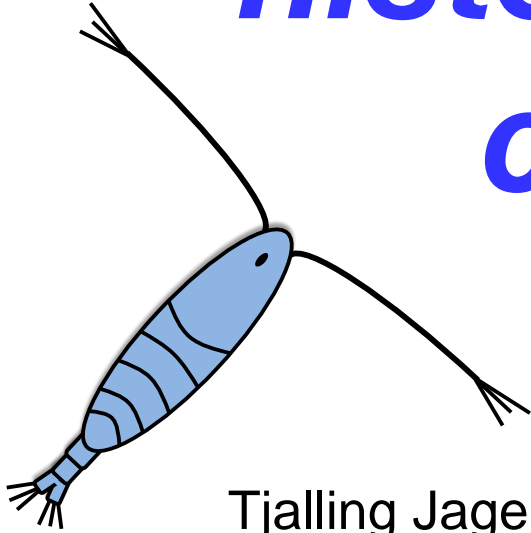
$\{j_{Xm}\}$

$f \cdot V^{2/3}$  with  $f = \dots$

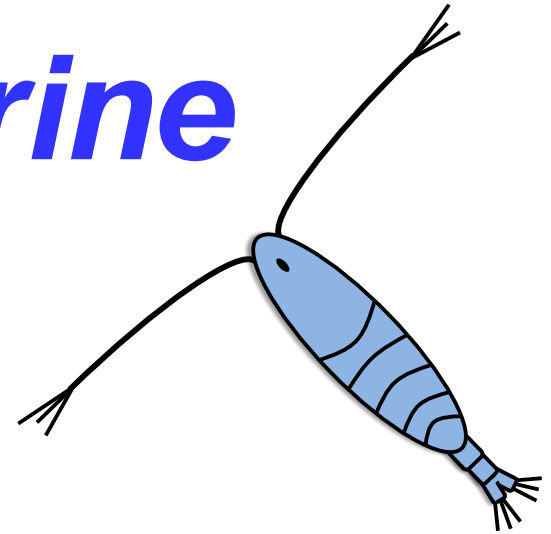
$\{j_{Xm}\}$

$\left( \frac{X_k}{X^* + X_k} \right)$

# The eccentric life history of marine copepods



Tjalling Jager  
Iurgi Salaberria  
Bjørn Henrik Hansen



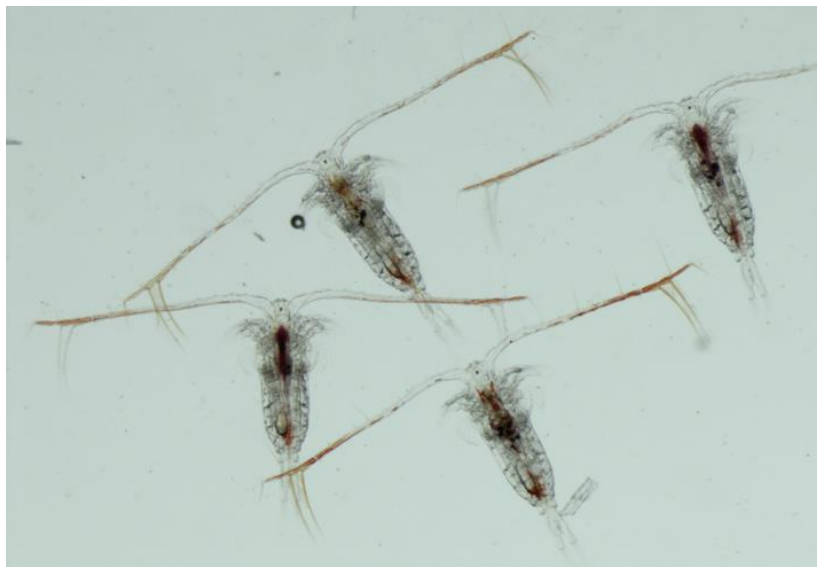
**DEBtox**  
Research



 **SINTEF**

# Project background

- Risk of oil and gas exploration to copepods
  - focus on Barents Sea
- Life cycle?



# Contents

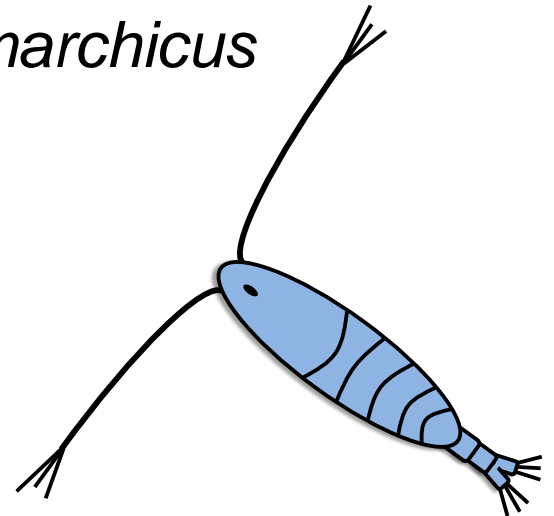
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## Long introduction

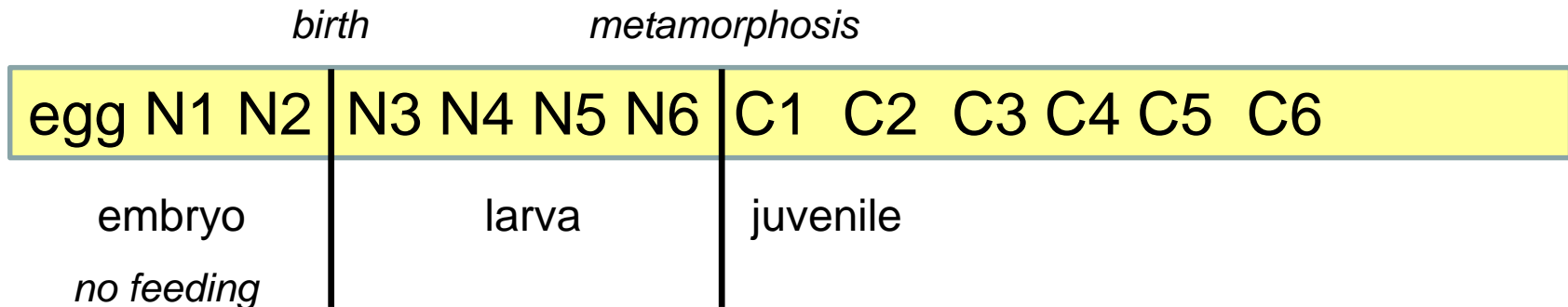
- Starting complex: what's special about Calanoid copepods?

## Work so far

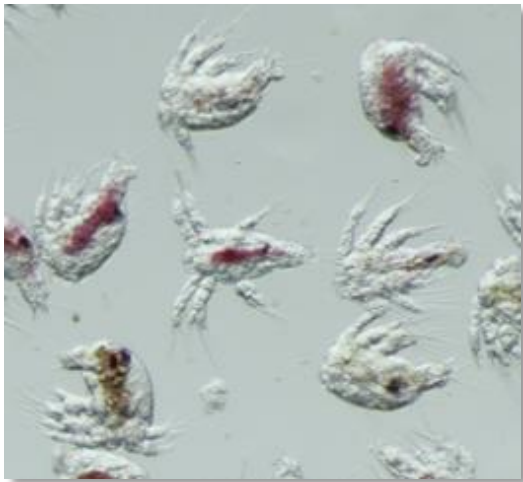
- Simplest analysis on *Calanus sinicus*
- More complex analysis on *Calanus finmarchicus*



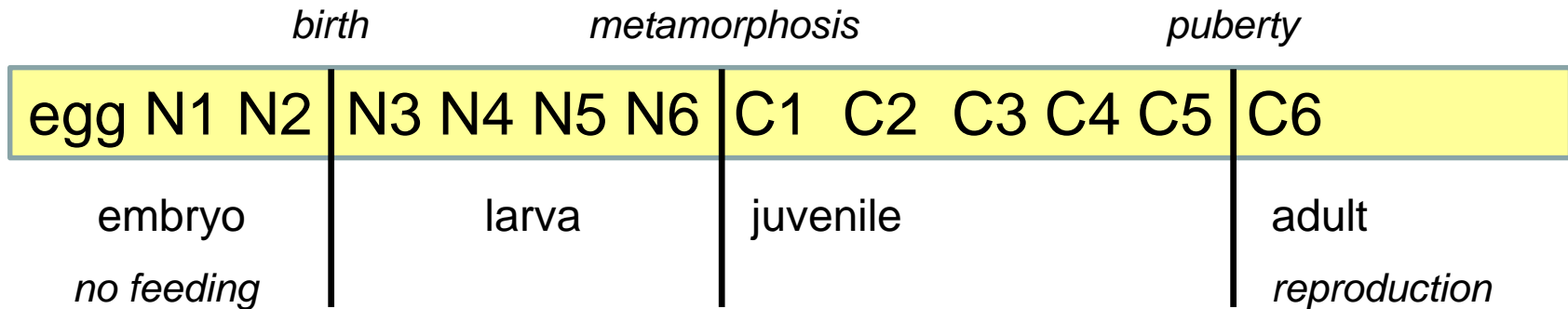
# Calanus life cycle



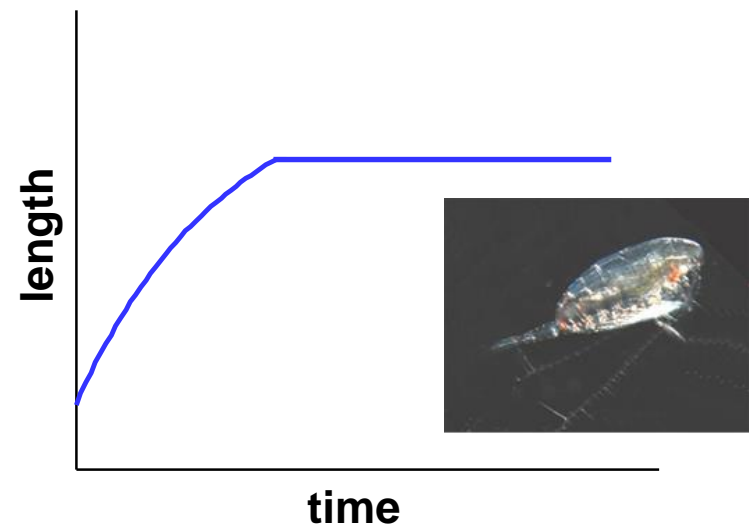
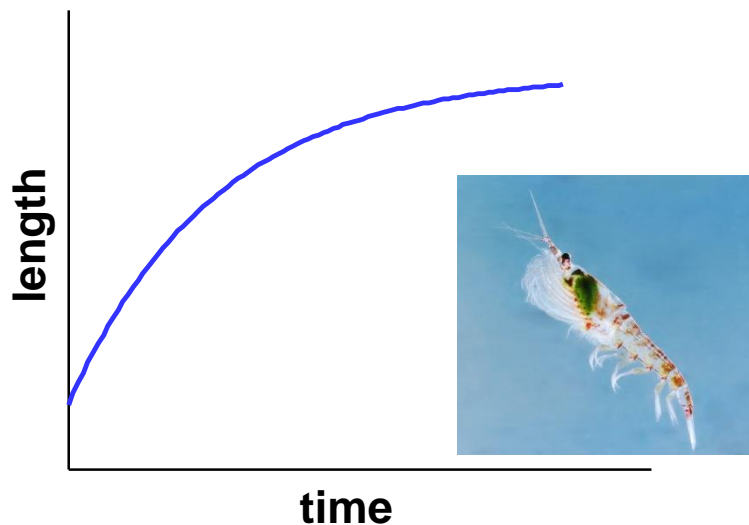
- Development with larval stages, and 'metamorphosis'
  - first two stages do not feed



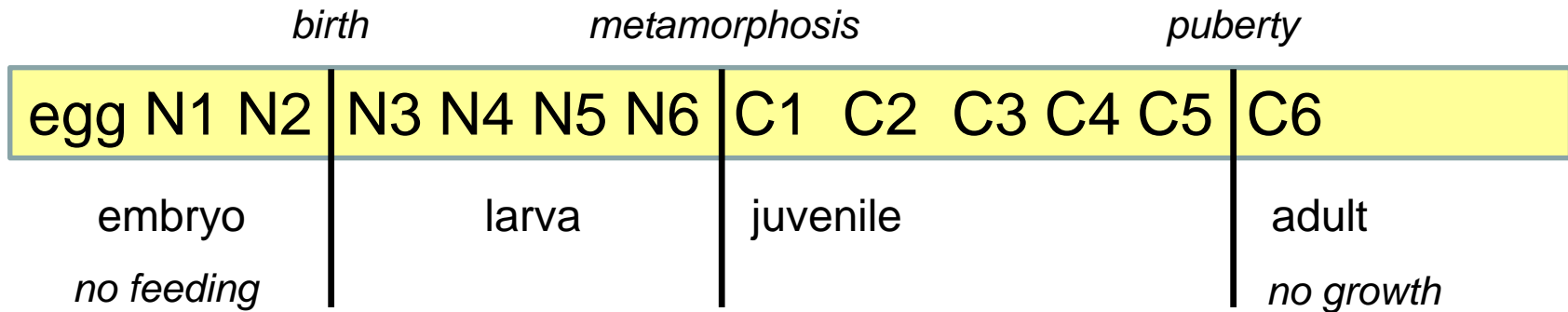
# Calanus life cycle



➤ Adults do *not* grow anymore, but reproduce



# Calanus life cycle

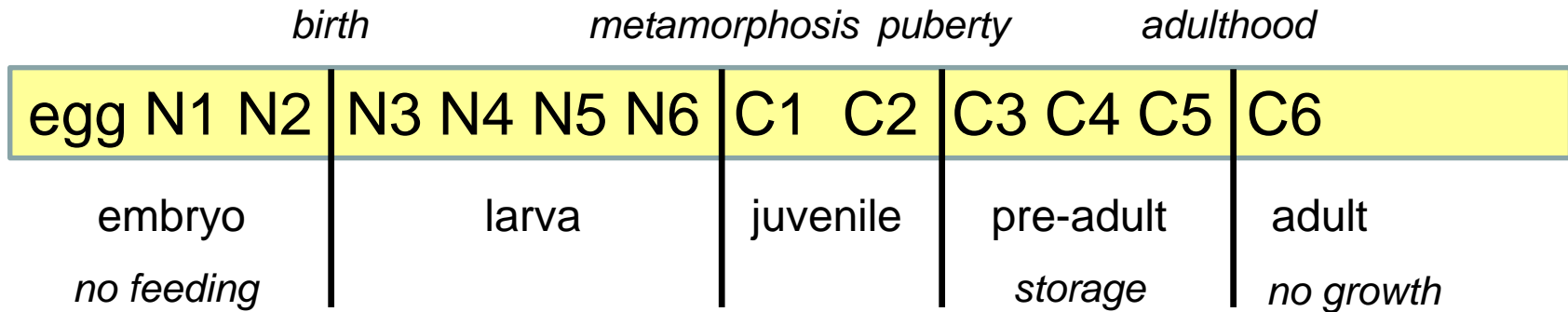


## ➤ Lipid storage

- starts at C3 and builds up over time
- view as ‘reproduction buffer’?



# Calanus life cycle

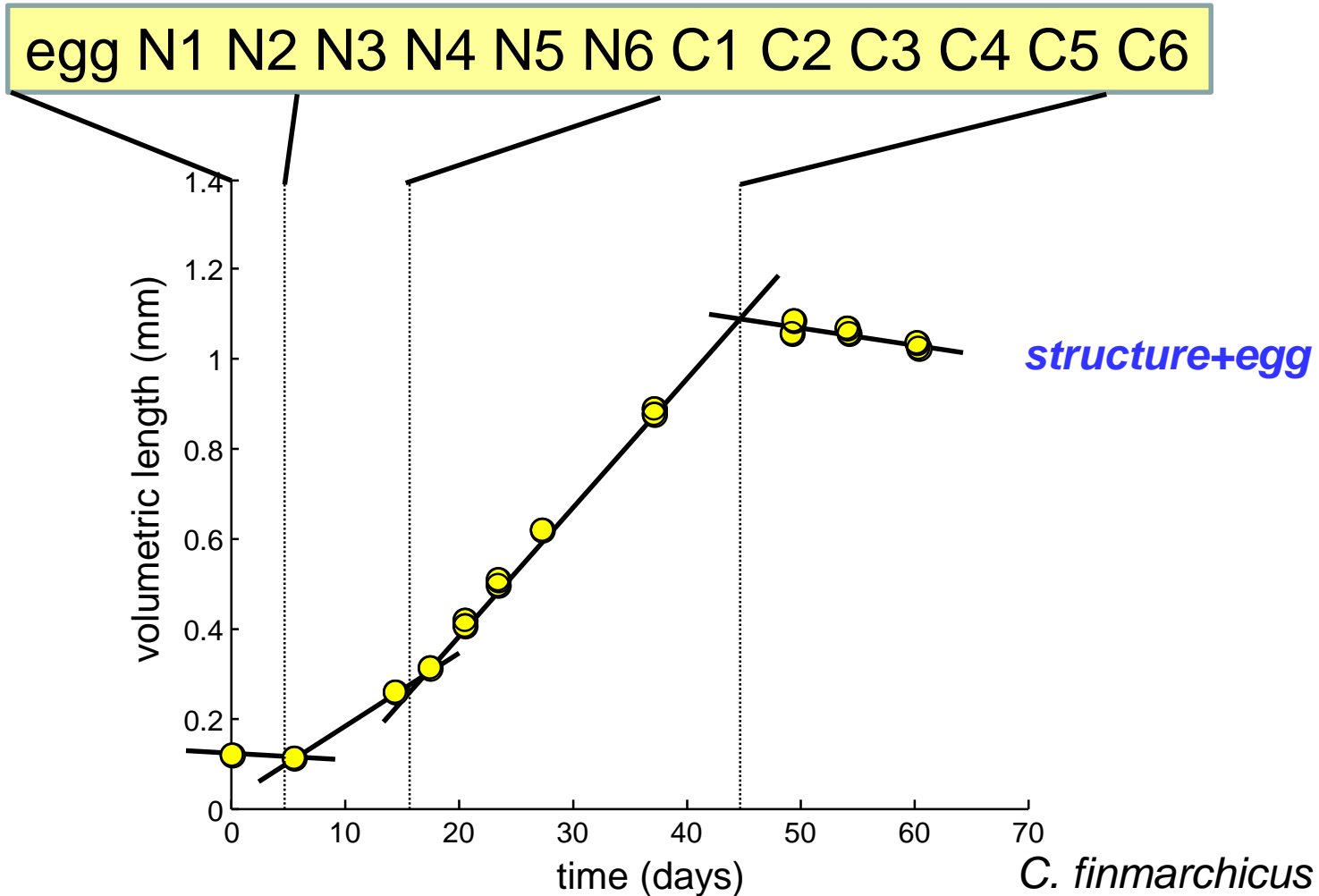


## ➤ Lipid storage

- starts at C3 and builds up over time
- view as ‘reproduction buffer’?



# Growth pattern

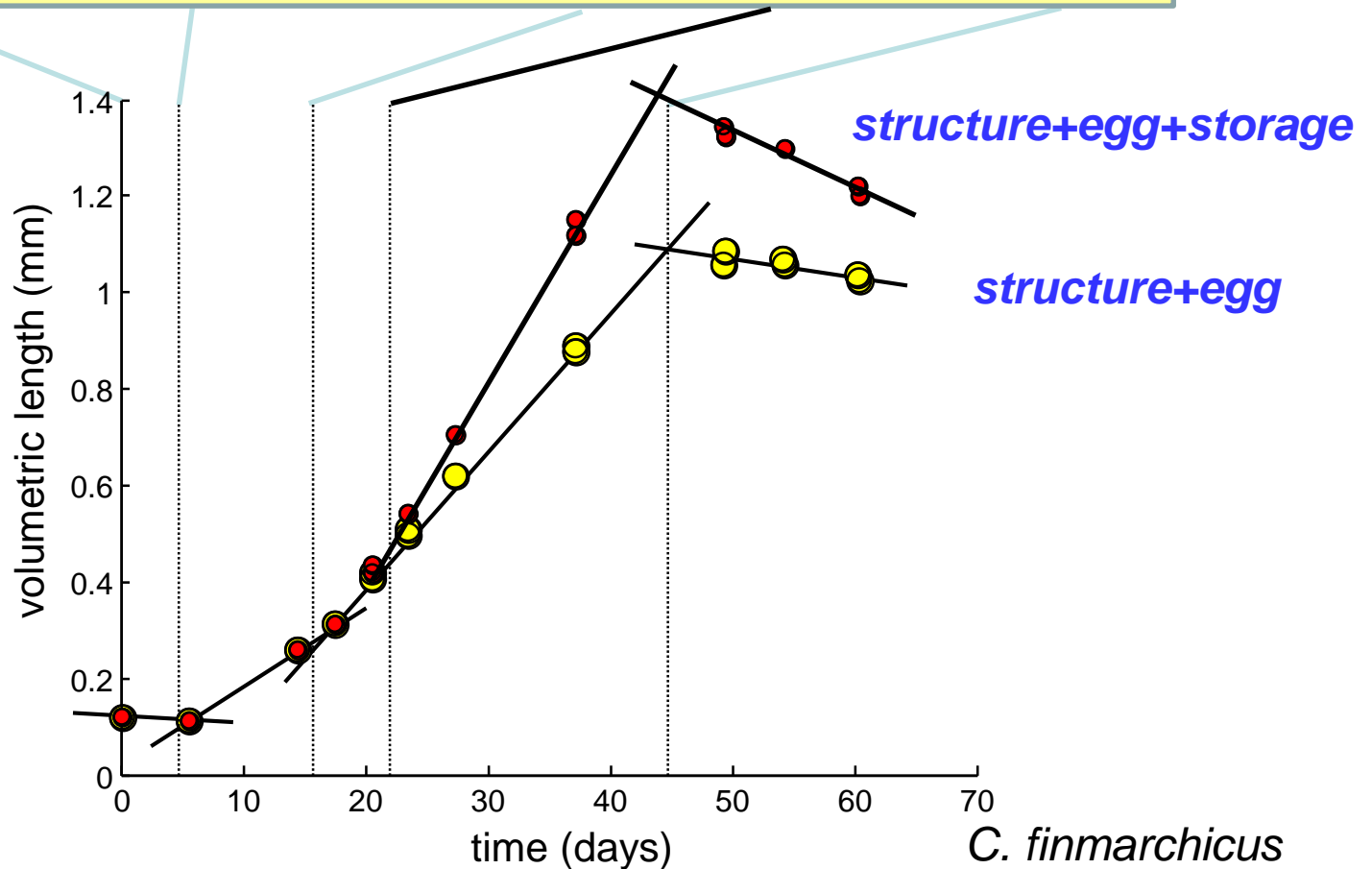


*C. finmarchicus*  
Campbell et al. (2001)



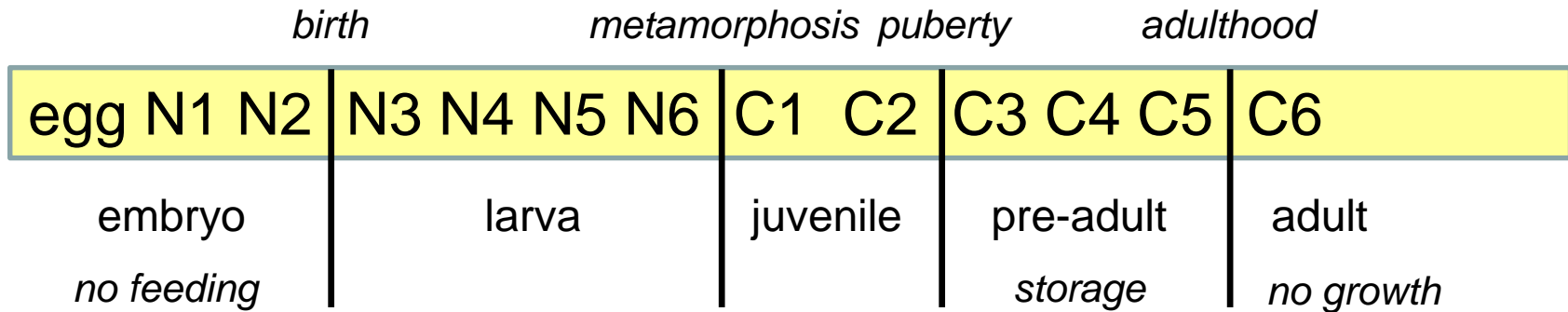
# Growth pattern

egg N1 N2 N3 N4 N5 N6 C1 C2 C3 C4 C5 C6



*C. finmarchicus*  
Campbell et al. (2001)

# Calanus life cycle



- Early adult loses lipids for a while
  - gonad maturation?
  - also in absence of food
- Split adult phase in two?



# Calanus life cycle

<i>birth</i>			<i>metamorphosis</i>				<i>puberty</i>			<i>adulthood</i>				
egg	N1	N2	N3	N4	N5	N6	C1	C2	C3	C4	C5	C6a	C6b	
embryo <i>no feeding</i>			larva				juvenile		pre-adult <i>storage</i>			immat. adult	mature adult	

- Early adult loses lipids for a while
  - gonad maturation?
  - also in absence of food
- Split adult phase in two?



# Calanus sinicus

- Start 'simple', with *C. sinicus* and DEBkiss
  - shelf waters of China, Korea and Japan
  - growth at various temperatures (Uye, 1988)
  - little lipid storage (and size determined as length)



Ecological Modelling 299 (2015) 114–120

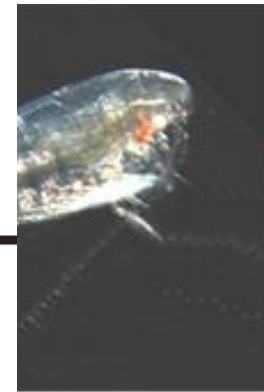


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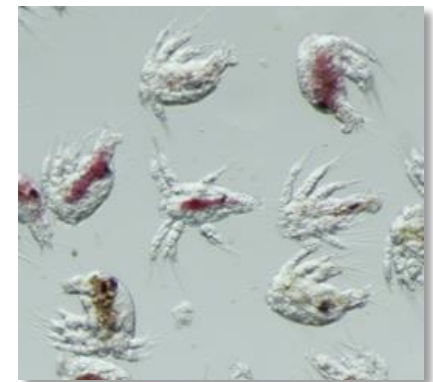
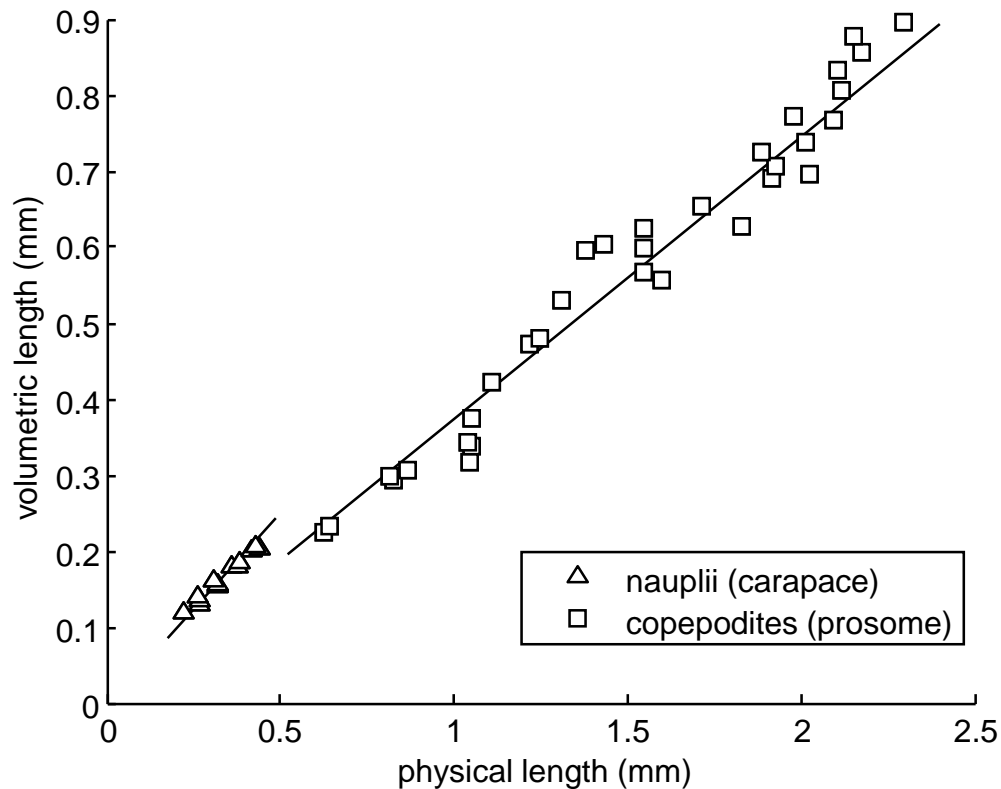


Capturing the life history of the marine copepod *Calanus sinicus* into a generic bioenergetics framework

Tjalling Jager<sup>a,\*</sup>, Iurgi Salaberria<sup>b</sup>, Bjørn Henrik Hansen<sup>b</sup>

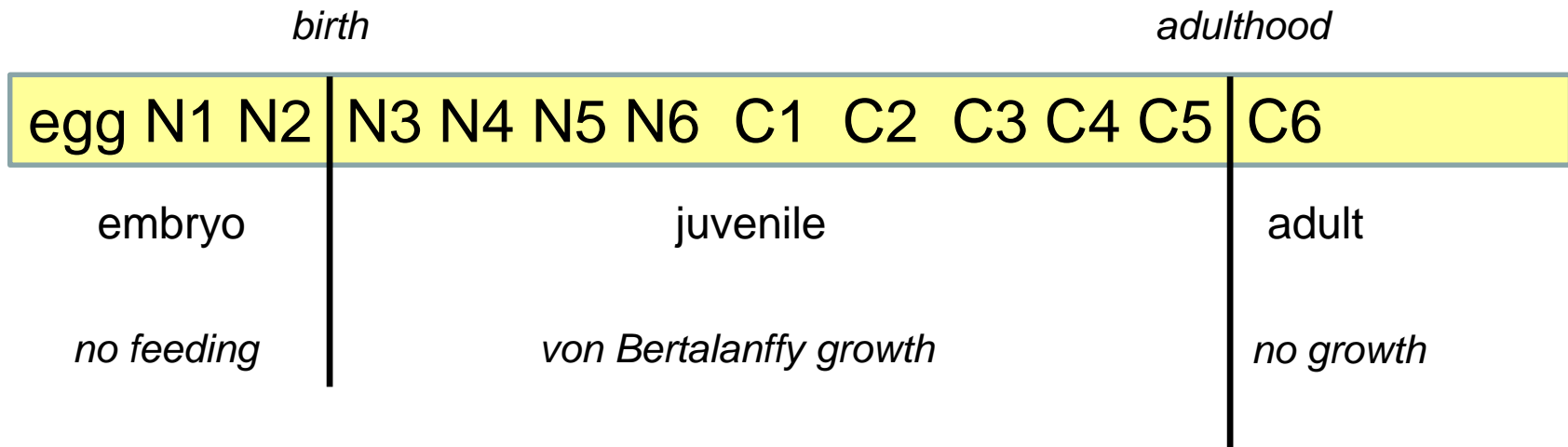
# Shape correction

- Larvae differ in shape from copepodites
  - no indication of storage ...



# *C. sinicus* growth

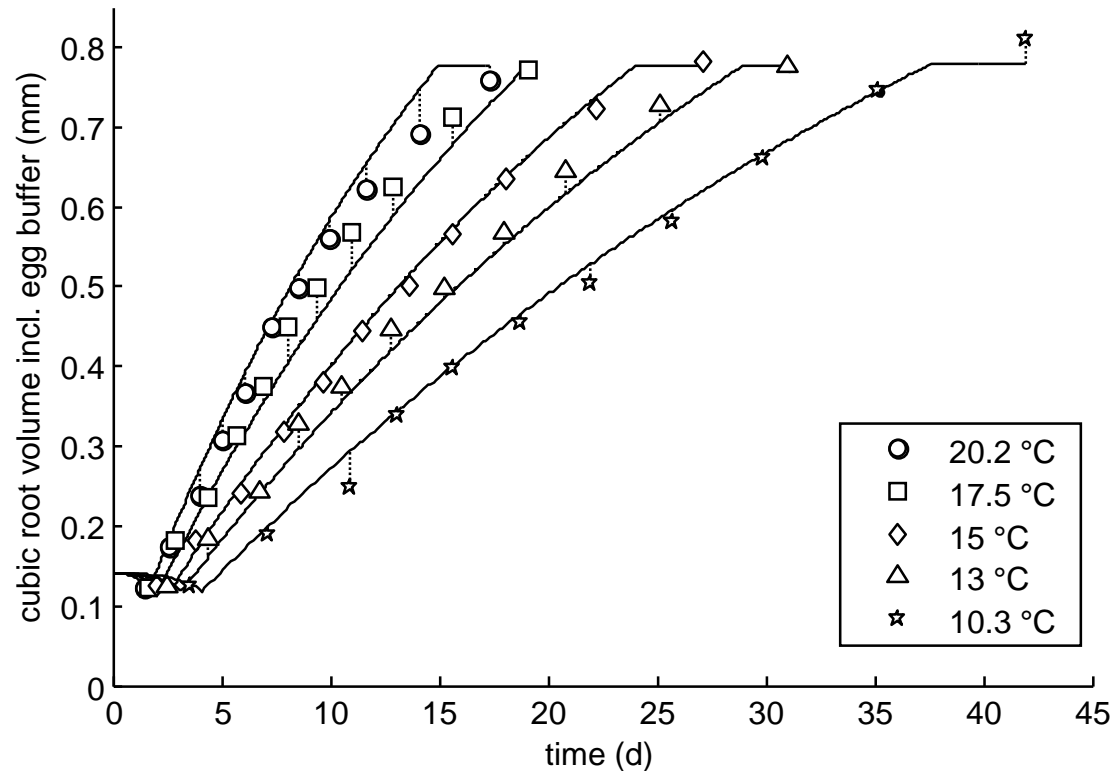
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- Zero-variate data points for time of stage transitions

# Growth

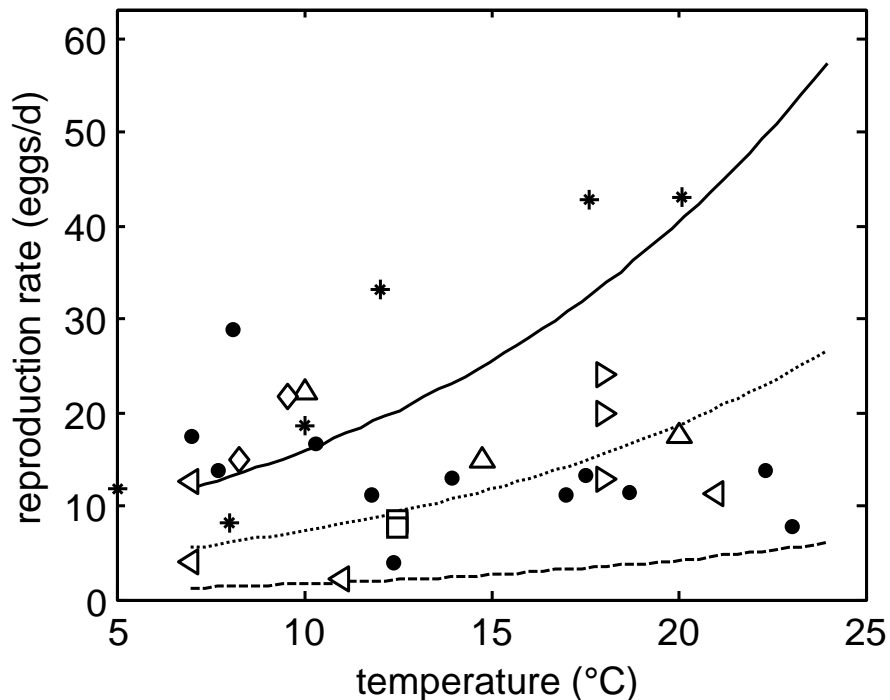
- Standard DEBkiss model, fix  $\kappa = 0.8$ 
  - embryo stage included
  - growth stops at critical size



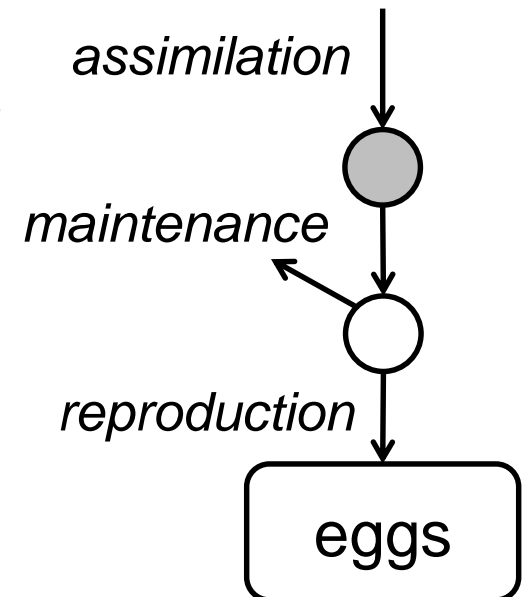
# Adult energetics

## Assume

- kappa rule is abandoned ...
- other primary pars. same as for earlier stages
- note: respiration and feeding also predicted fairly well



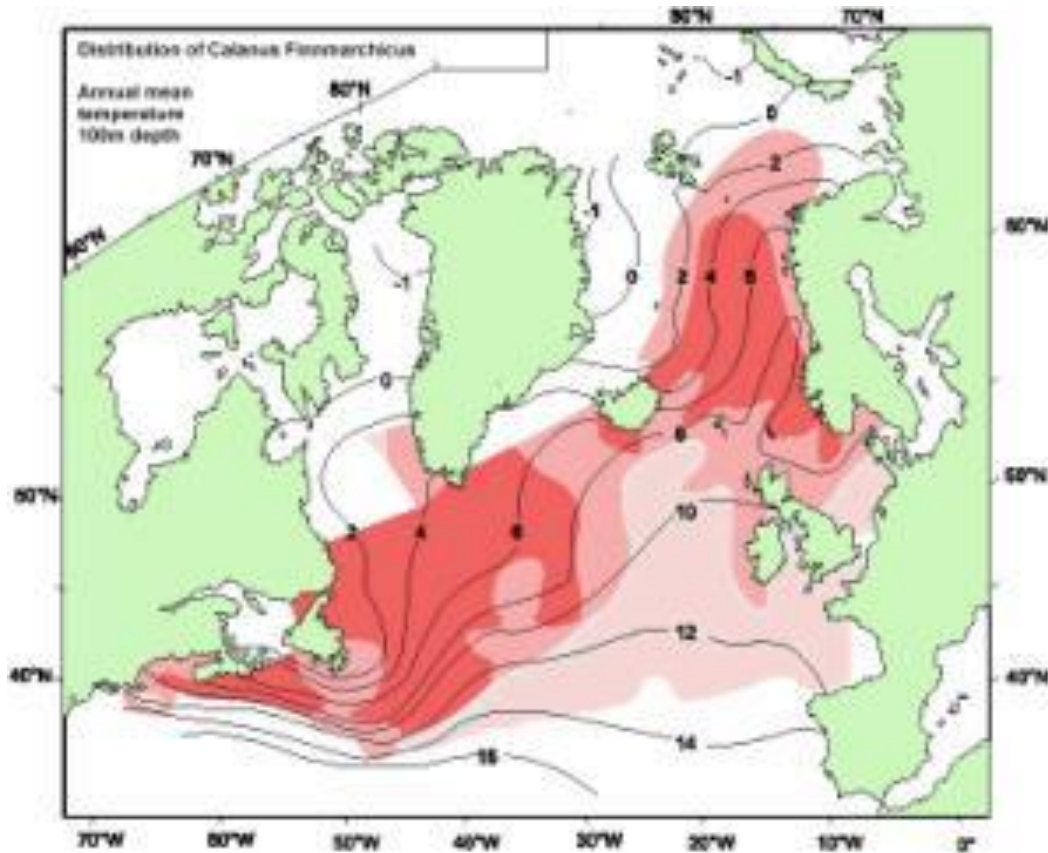
—  $f = 1$   
.....  $f = 0.7$   
- - -  $f = 0.5$





# *Calanus finmarchicus*

- Widely distributed in North Atlantic



# Calanus finmarchicus

---

- Focus on lipid storage, which is essential ...
  - for interpreting body weight/composition
  - for overwintering/reproduction success
  - for toxicokinetics and effects ...
- Data set of Campbell *et al.* (2001)
  - followed C and N over time
  - different temperatures
  - limiting food levels
- Assume
  - C:N of structure is 4
  - lipid has no N
  - switch at structural length



# Modifications

---

- Patterns regarding growth rate
  - embryos/nauplii slower than copepodites

*Lower  $f$  before C1*

- Patterns regarding maximum size:
  - at high temperature, max. size is smaller
  - at low food, max. size is smaller

*Ignore for now*

*Different critical length*

- Patterns regarding storage:
  - at low food, little or no storage build up
  - in early adult, storage declines

*Different  $\kappa$  per food lvl.*

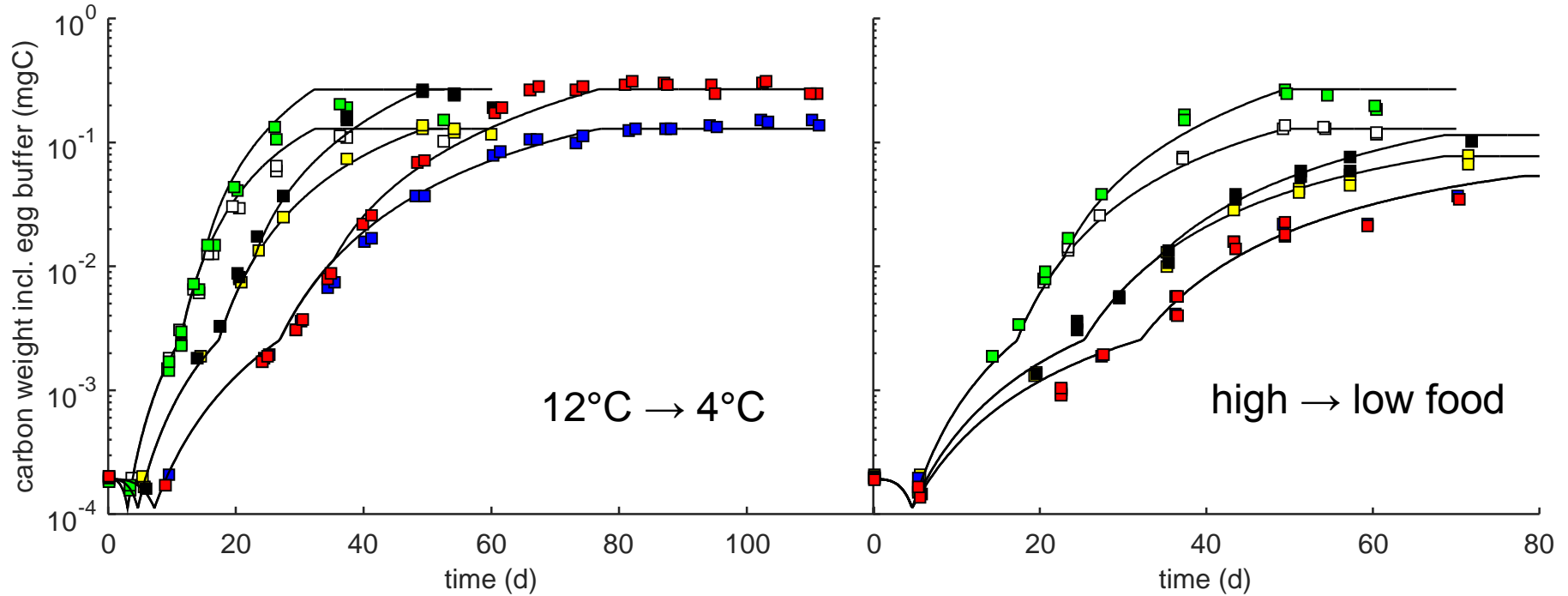
*Ignore for now*

- Fitting issues:
  - insufficient info to fix switches
  - insufficient info to fix maintenance

*zero-var. data*

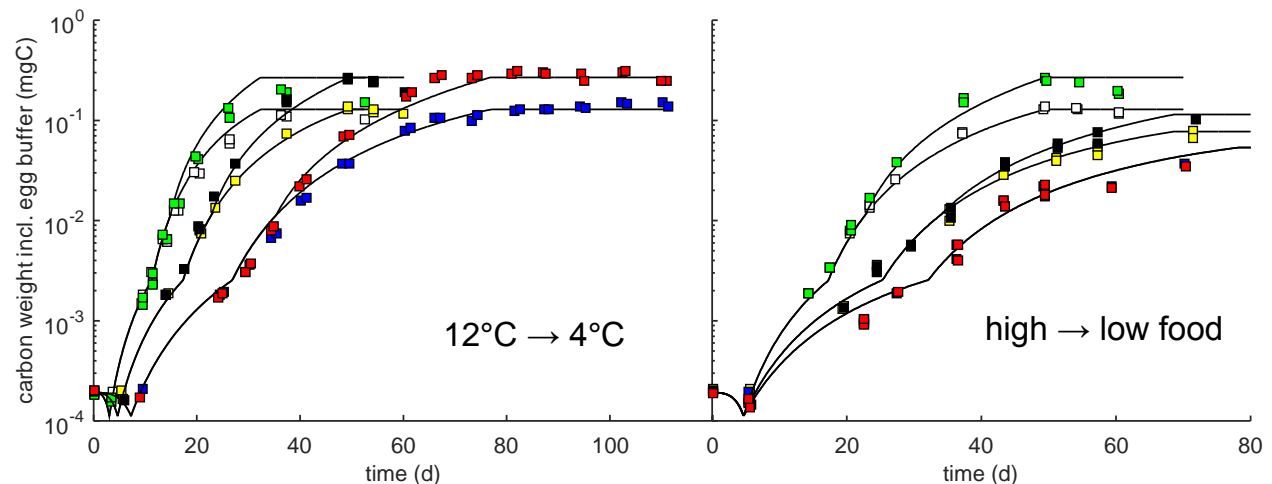
*use respiration?*

# Preliminary fits



# Conclusions fits

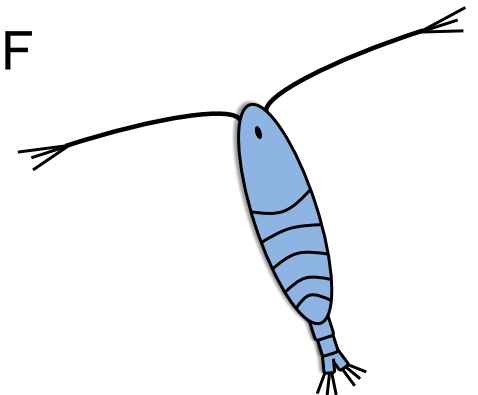
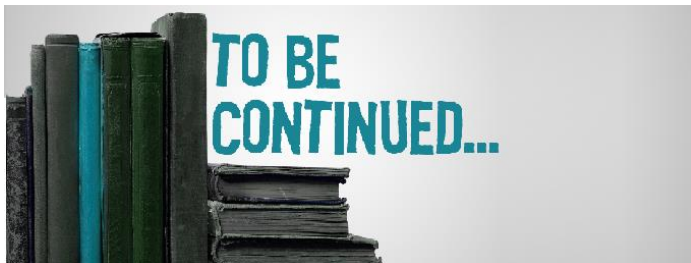
- Switch in feeding rate at C1 works well
- Treating lipid storage as repro buffer fits well
  - increase  $\kappa$  at low food works but is ugly ...
- Size-at-stage depends on temperature and food ...
  - length is poor proxy for development stage ...
  - simultaneous maturation and storage in  $1-\kappa$  branch?



# Take home ...

---

- Calanoid copepods have a tricky life history
  - switches, storage, determinate growth ...
  - remarkable similarities to holometabolic insects
- Lipid sac is best viewed as a repro buffer
  - possibly, maturation and buffer build-up compete ...
- Present data sets are limited ...
  - insufficient power to test all (potential) model modifications
  - dedicated experimental work ongoing at SINTEF





## ***Funding***

225314/E40



**The Research Council  
of Norway**

## ***More information***

**[www.debttox.info](http://www.debttox.info)**

summercourse 'DEBtox' 2016 (DK)

**[www.sintef.no/projectweb/calanus---home/](http://www.sintef.no/projectweb/calanus---home/)**

