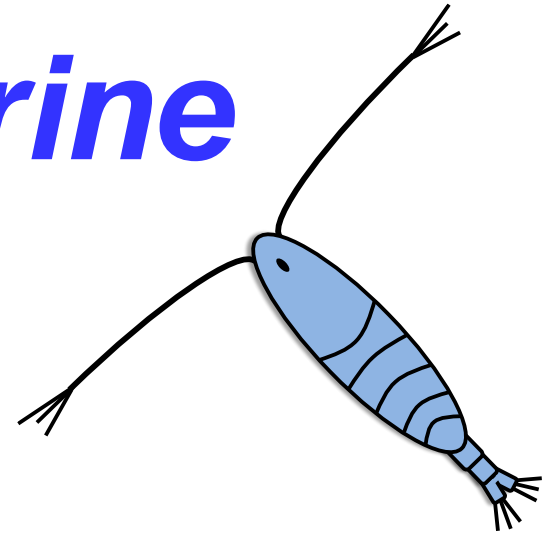
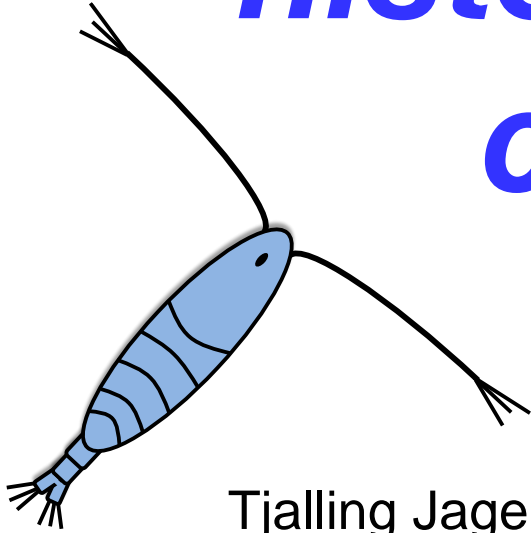


$$\begin{aligned}
 & \frac{[E]}{[E_G] + \kappa [E]} \\
 & \left(\frac{[E_G] \cdot \{ \dot{P}_{Am} \}}{[E_m]} \right)^{2/3} + \left(\frac{X_k}{X_m + X_k} \right) \\
 & \text{with } f = \left(\frac{X_k}{X_m + X_k} \right) \\
 & \text{with } \bar{f} = \left(\frac{X_k}{X_m + X_k} \right)
 \end{aligned}$$

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?



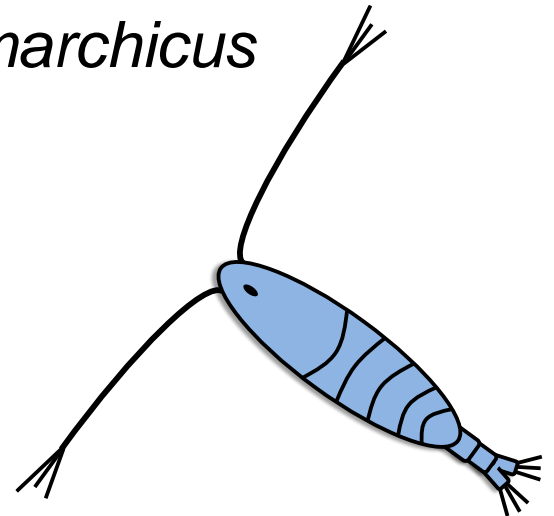
Contents

Long introduction

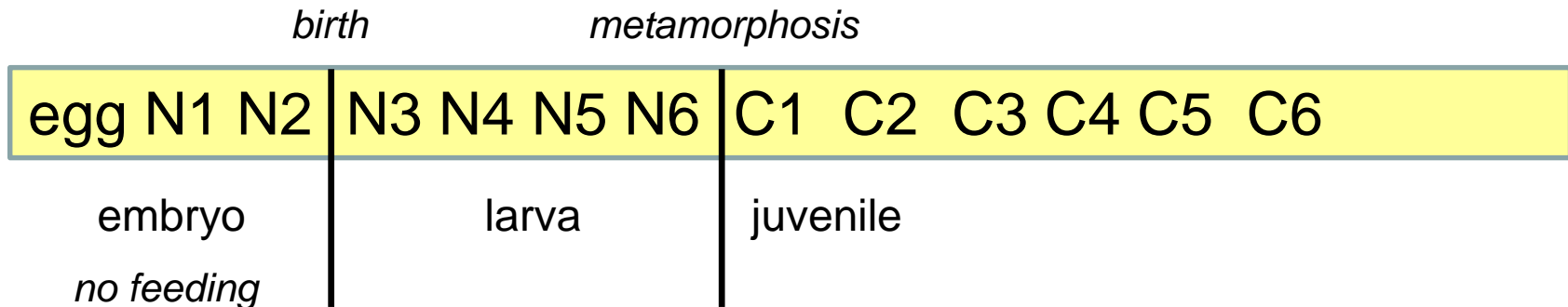
- Starting complex: what's special about Calanoid copepods?

Work so far

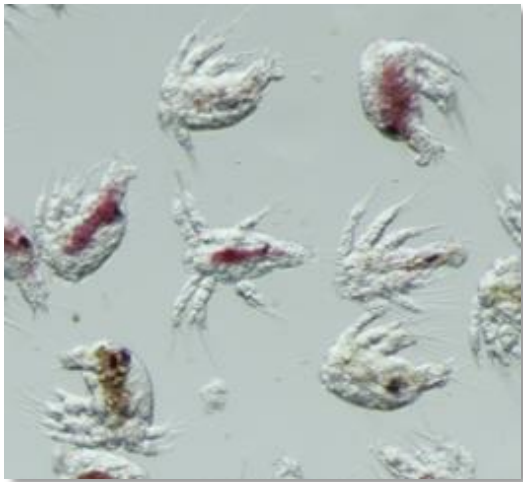
- Simplest analysis on *Calanus sinicus*
- More complex analysis on *Calanus finmarchicus*



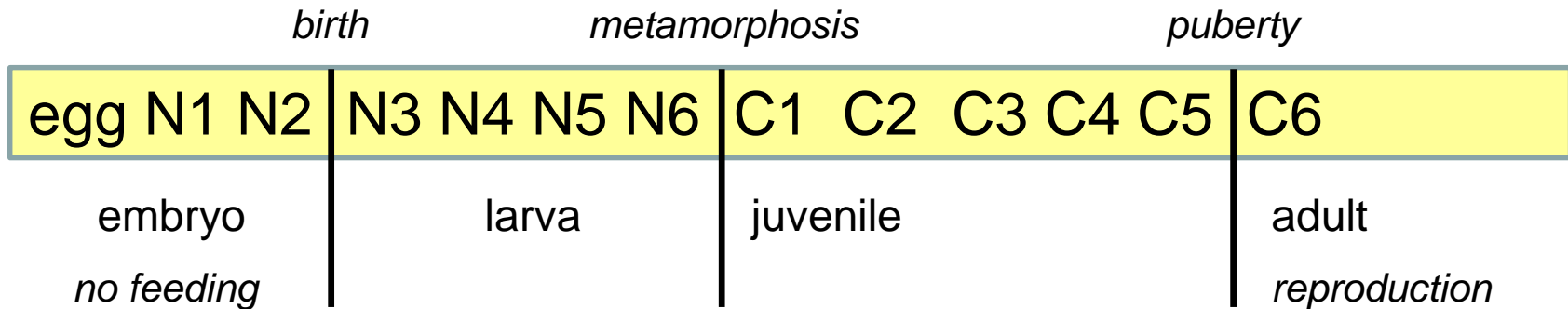
Calanus life cycle



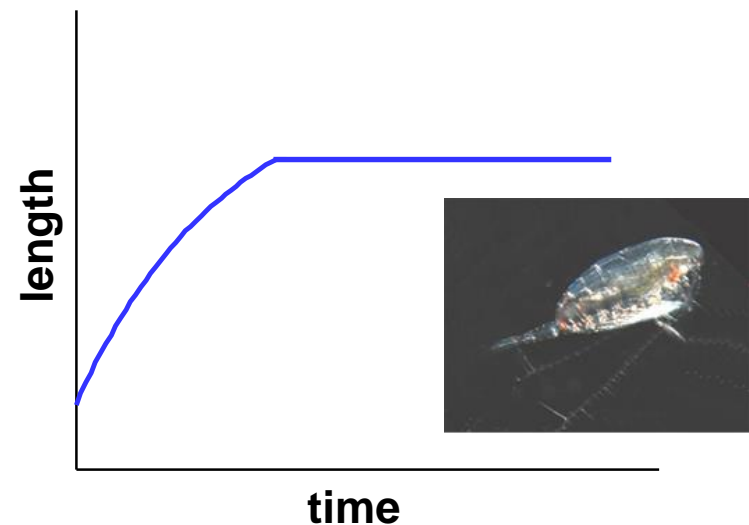
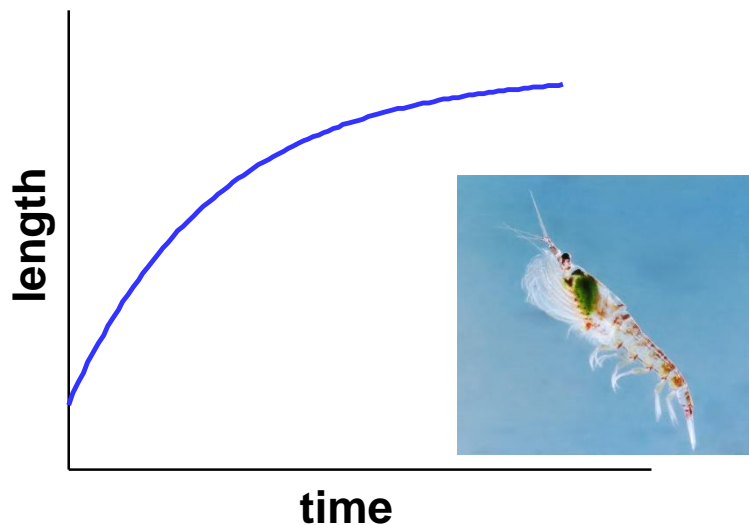
- Development with larval stages, and 'metamorphosis'
 - first two stages do not feed



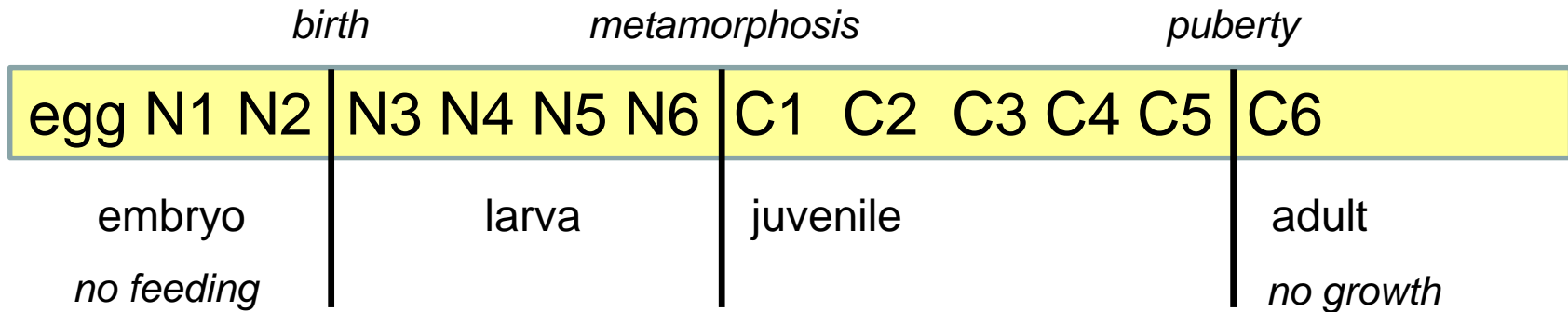
Calanus life cycle



➤ Adults do *not* grow anymore, but reproduce



Calanus life cycle

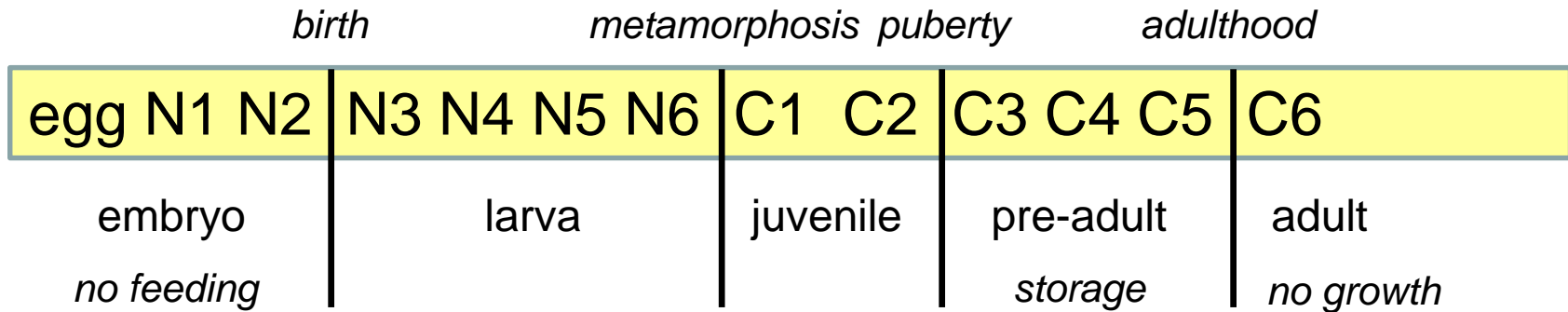


➤ Lipid storage

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



Calanus life cycle

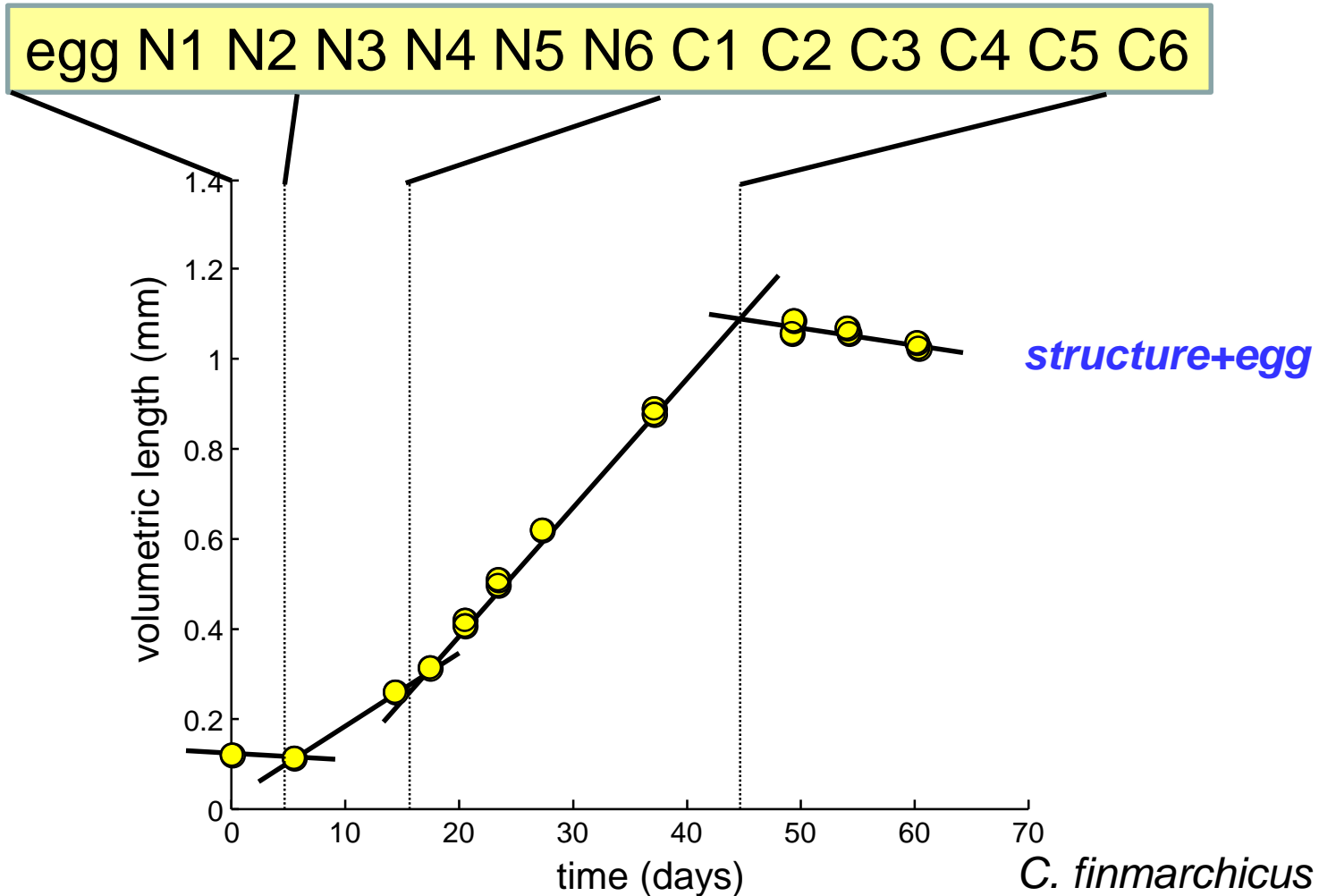


➤ Lipid storage

- starts at C3 and builds up over time
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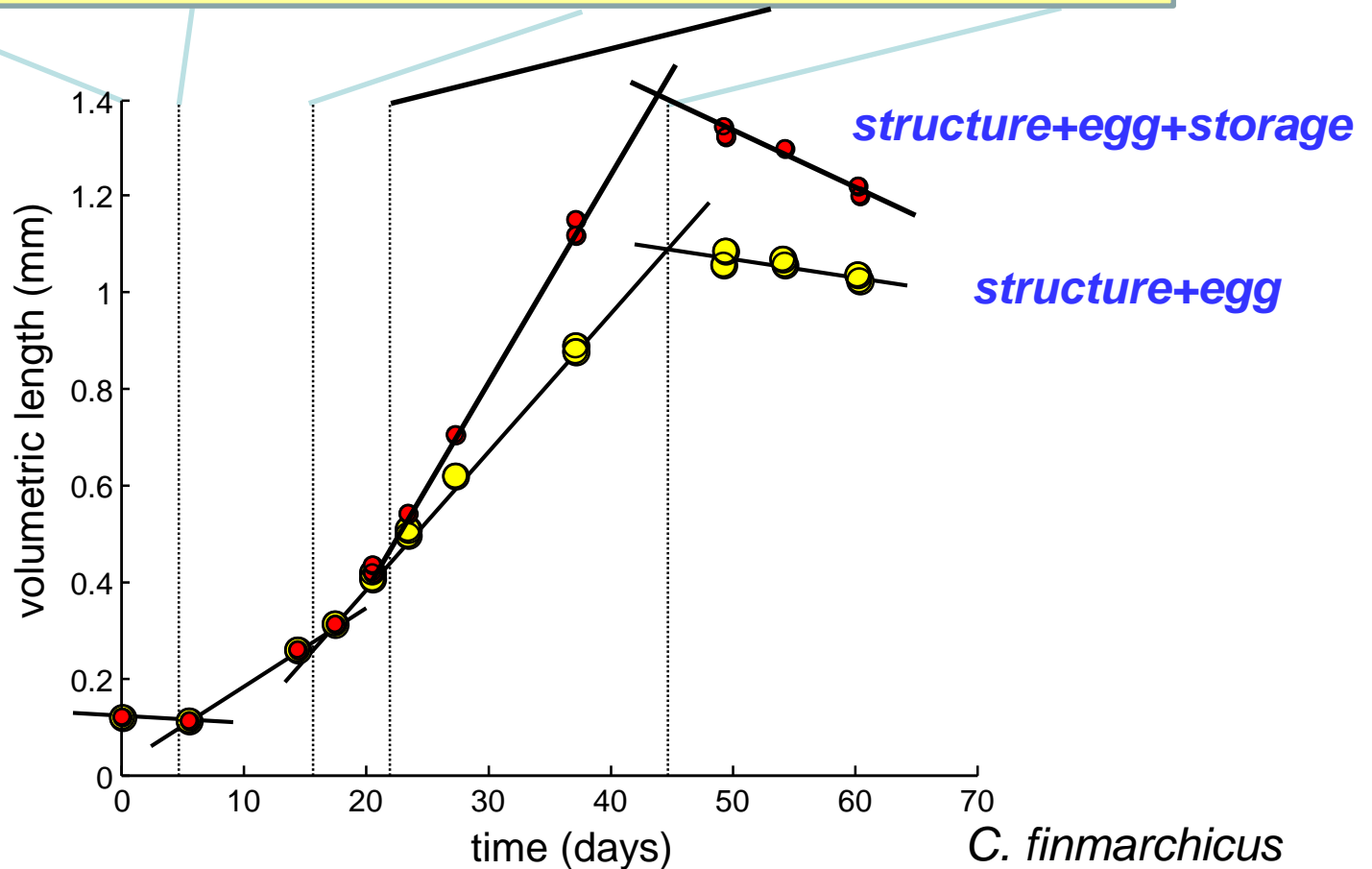
Growth pattern



C. finmarchicus
Campbell et al. (2001)

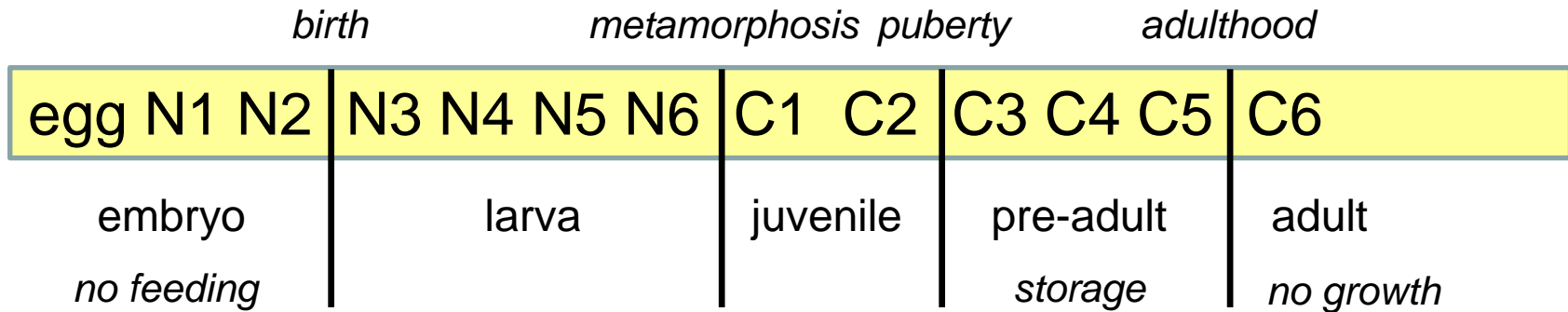
Growth pattern

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

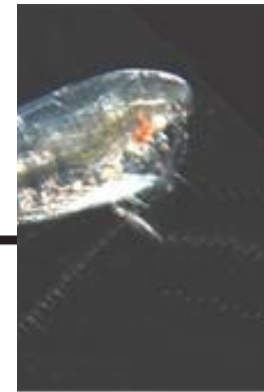


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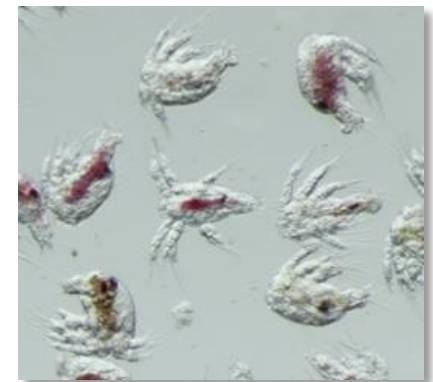
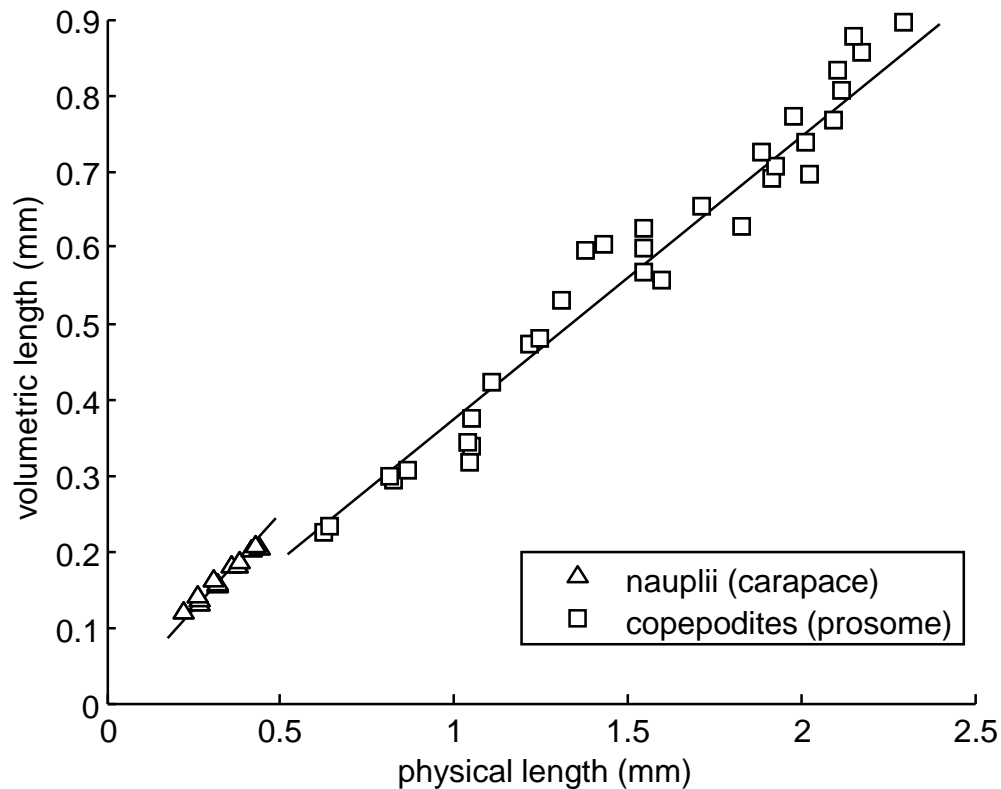


Capturing the life history of the marine copepod *Calanus sinicus* into a generic bioenergetics framework

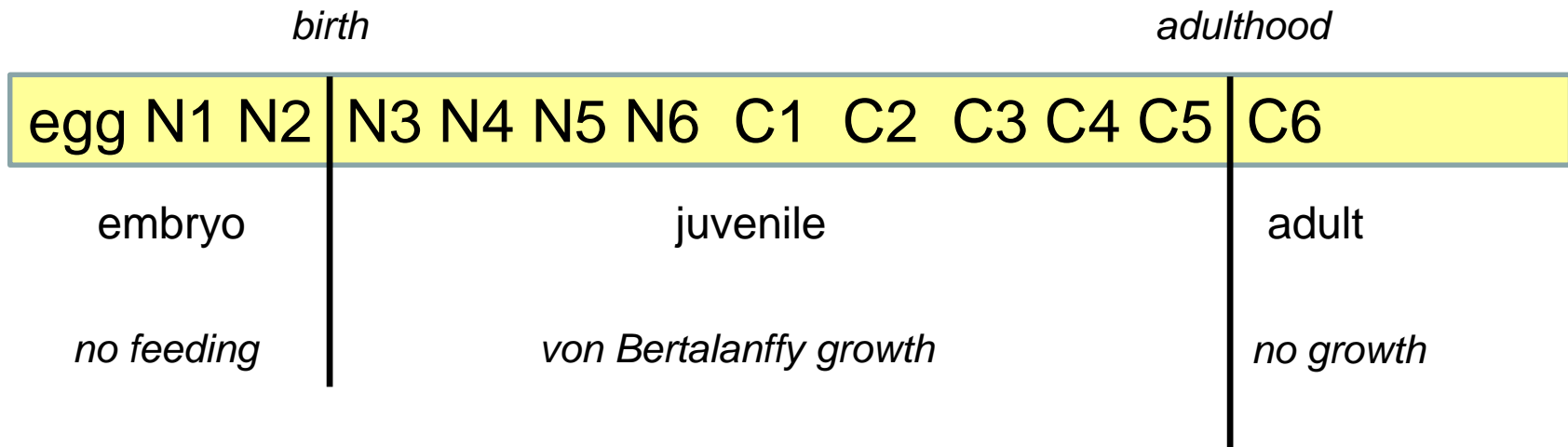
Tjalling Jager^{a,*}, Iurgi Salaberria^b, Bjørn Henrik Hansen^b

Shape correction

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



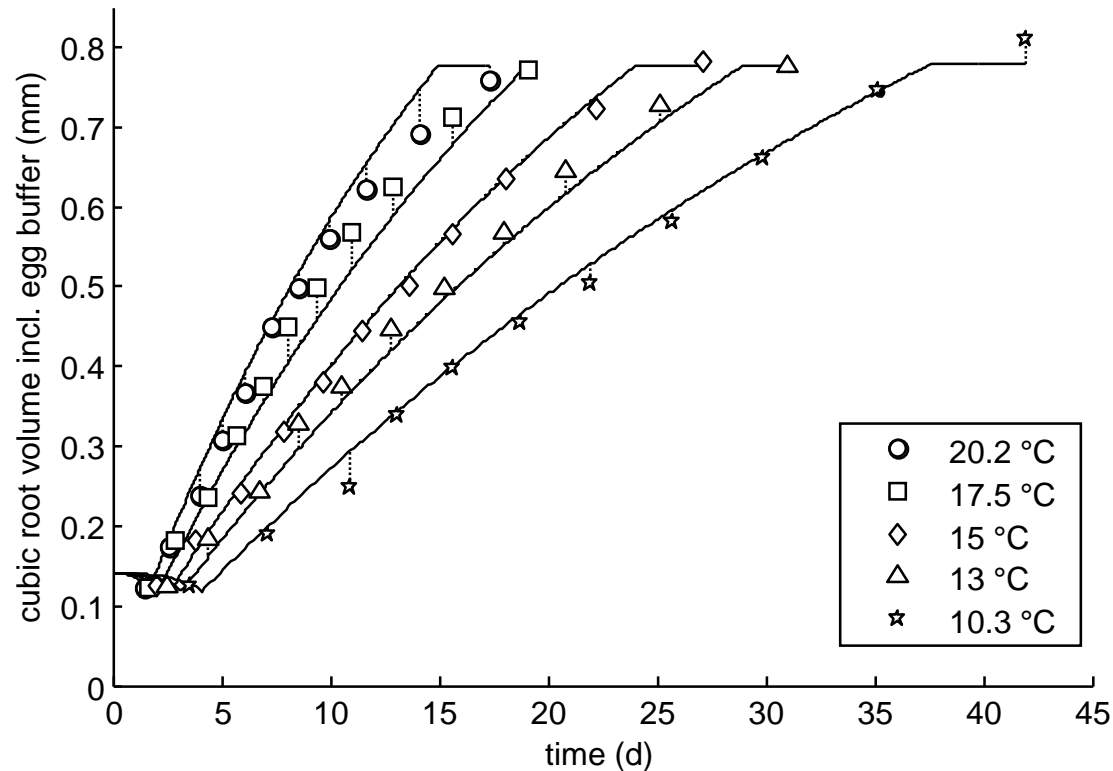
C. sinicus growth



- Zero-variate data points for time of stage transitions

Growth

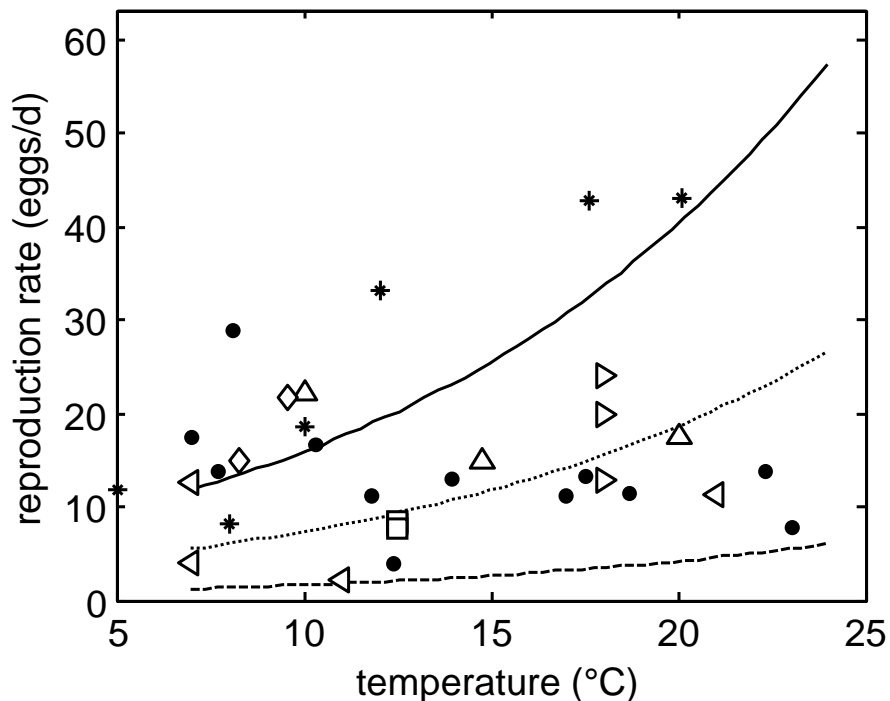
- Standard DEBkiss model, fix $\kappa = 0.8$
 - embryo stage included
 - growth stops at critical size



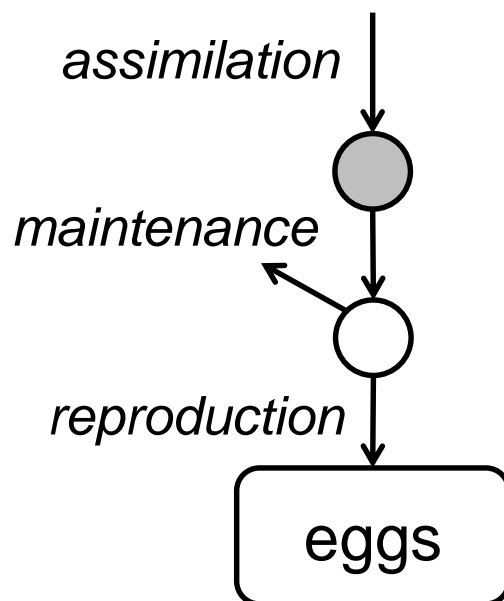
Adult energetics

Assume

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

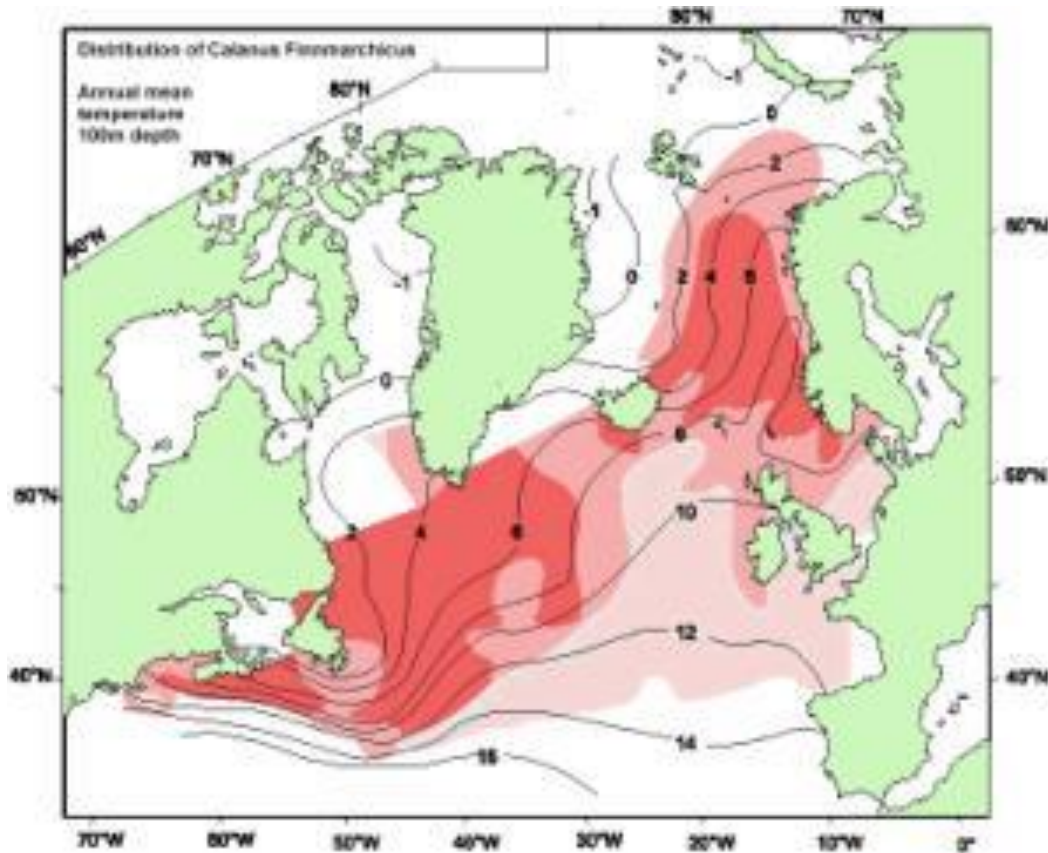


— $f = 1$
..... $f = 0.7$
- - - $f = 0.5$



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 κ per food lvl.

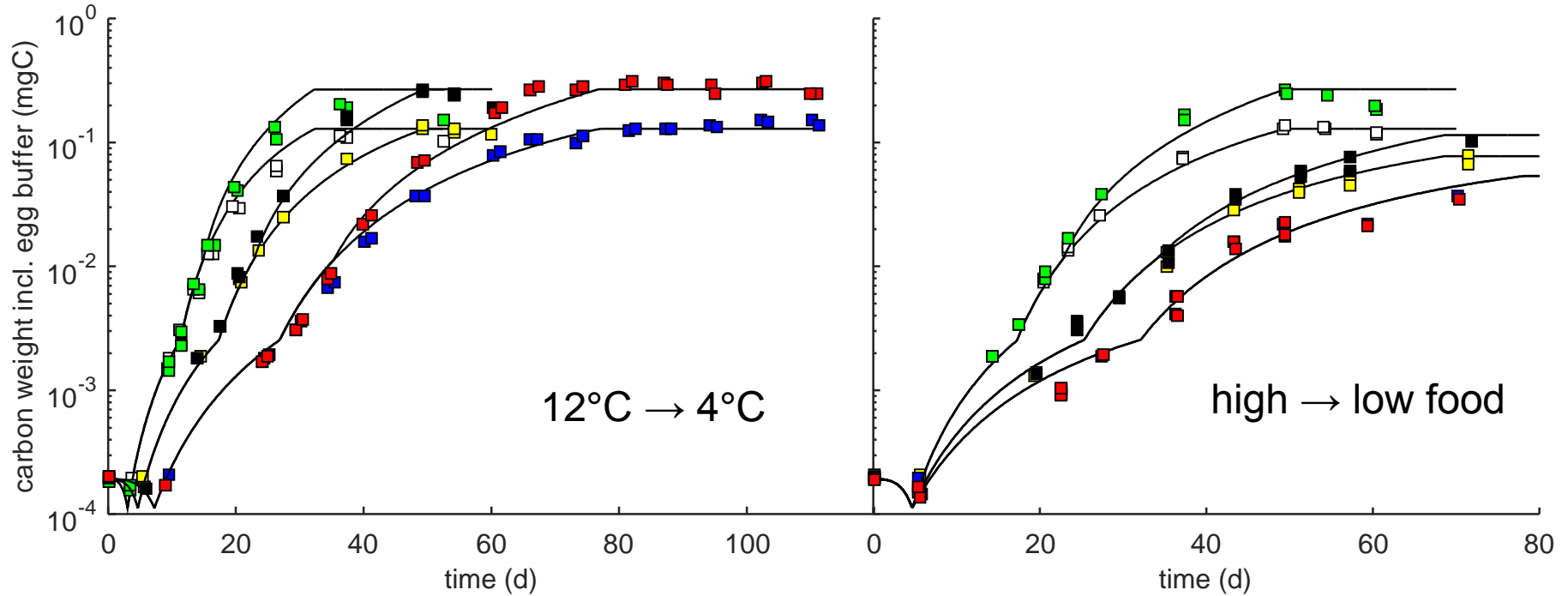
Ignore for now

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

zero-var. data

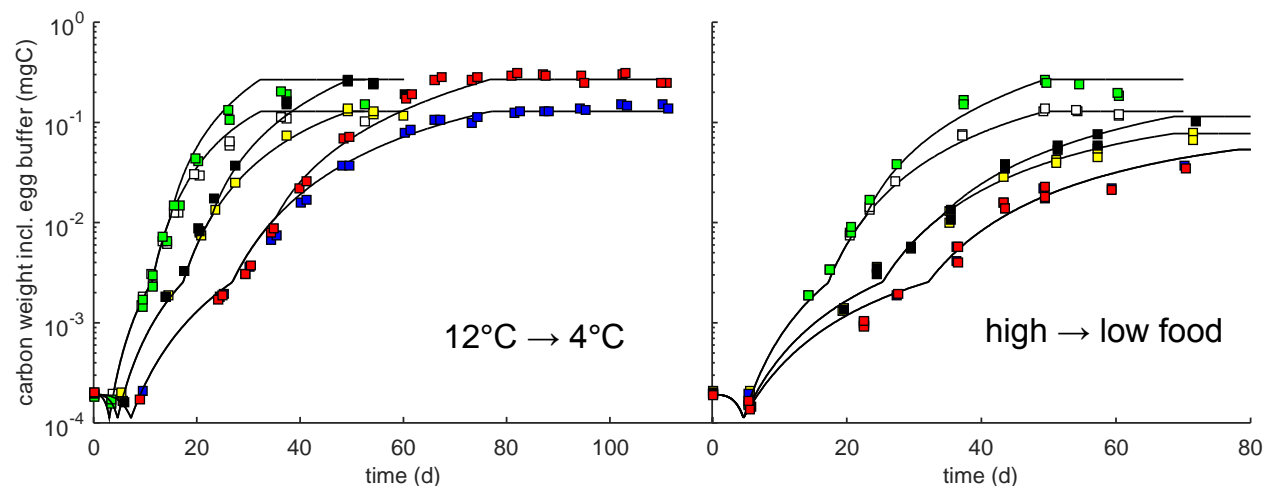
use respiration?

Preliminary fits



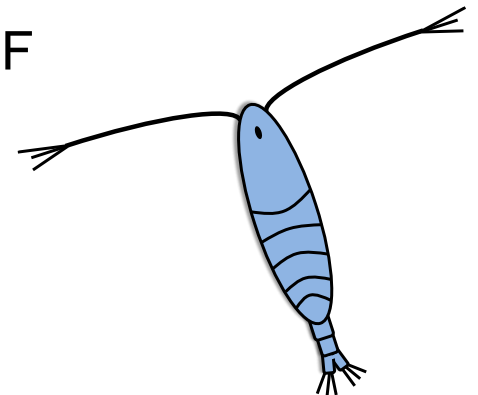
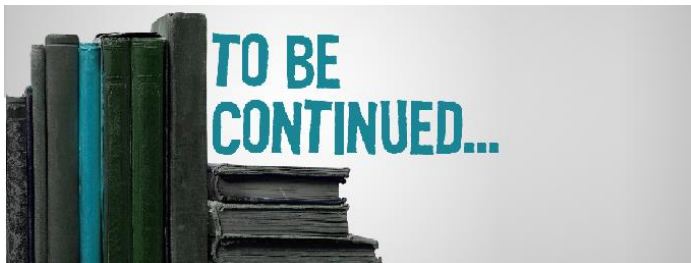
Conclusions fits

- Switch in feeding rate at C1 works well
- Treating lipid storage as repro buffer fits well
 - increase κ 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

summercourse 'DEBtox' 2016 (DK)

www.sintef.no/projectweb/calanus---home/

