Prey stoichiometry, primary production, and plankton composition influence production of marine crustacean zooplankton

Pei-Chi Ho[1], Esther Wong[2], Fan-Sian Lin[1] Akash R. Sastri[3,4], Carmen García-Comas[5], Noboru Okuda[6], Fuh-Kwo Shiah[7], Gwo-Ching Gong[8,9], Rita S.W. Yam[10], Chih-hao Hsieh[1, 7, 11, 12]

1. Institute of Oceanography, National Taiwan University, Taipei, Taiwan. 2. Division of Life Science, Hong Kong University of Science and Technology, Clear Water Bay, Hong Kong. 3. Department of Biology, University of Victoria, Victoria, BC, Canada. 4. Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney, BC, Canada. 5. Institute of Marine Sciences (ICM-CSIC), Barcelona, Spain 6. Research Institute for Humanity & Nature, Kyoto, Japan. 7. Research Center for Environmental Changes, Academia Sinica, Taipei, Taiwan. 8. Institute of Marine Environment and Ecology, National Taiwan Ocean University, Keelung, Taiwan. 9. Center of Excellence for the Oceans, National Taiwan Ocean University, Keelung, Taiwan. 10. Department of Bioenvironmental Systems Engineering, National Taiwan University, Taipei, Taiwan. 11. Institute of Ecology and Evolutionary Biology, Department of Life Science, National Taiwan University, Taipei, Taiwan. 12. National Center for Theoretical Sciences, Taipei, Taiwan.

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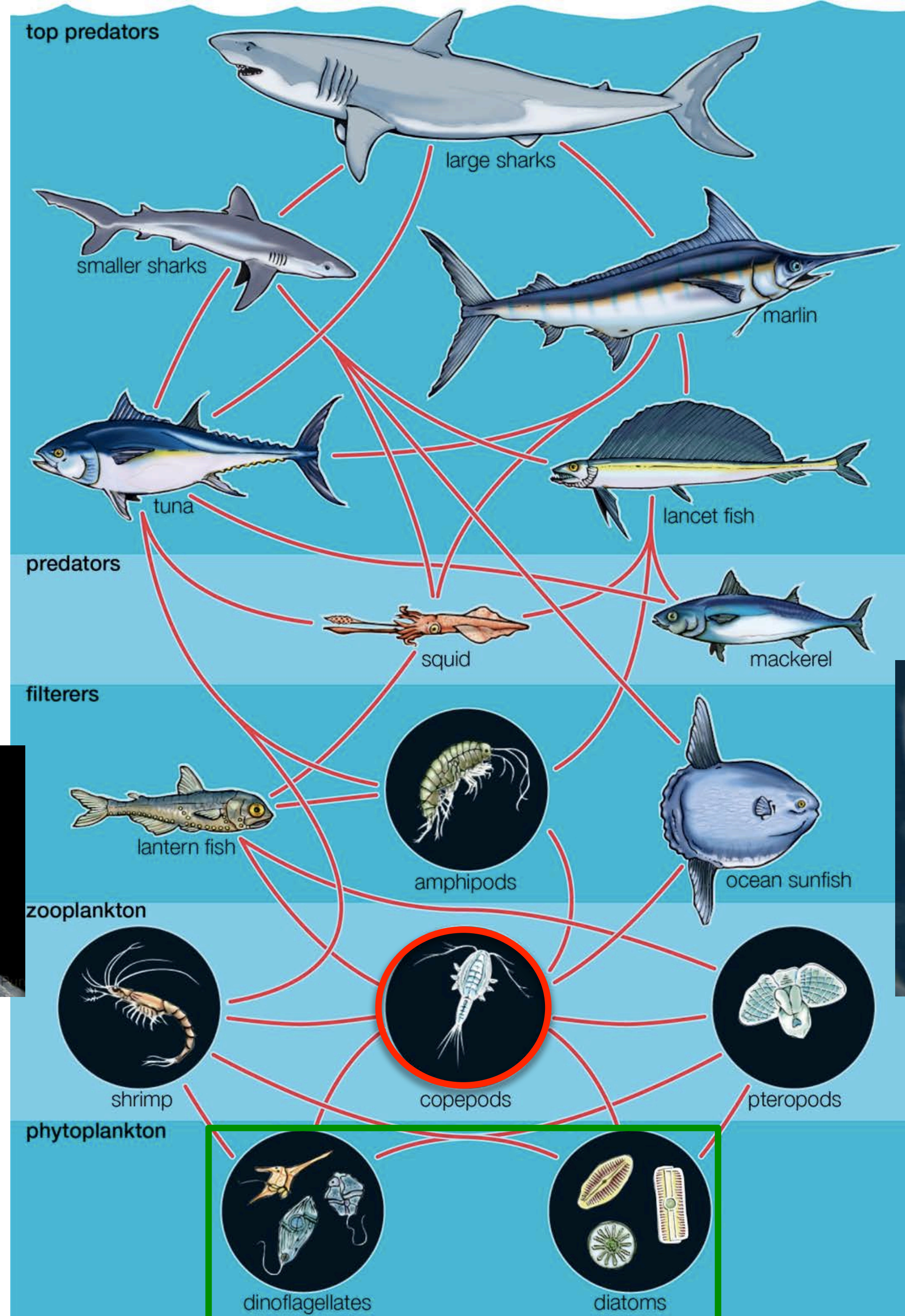
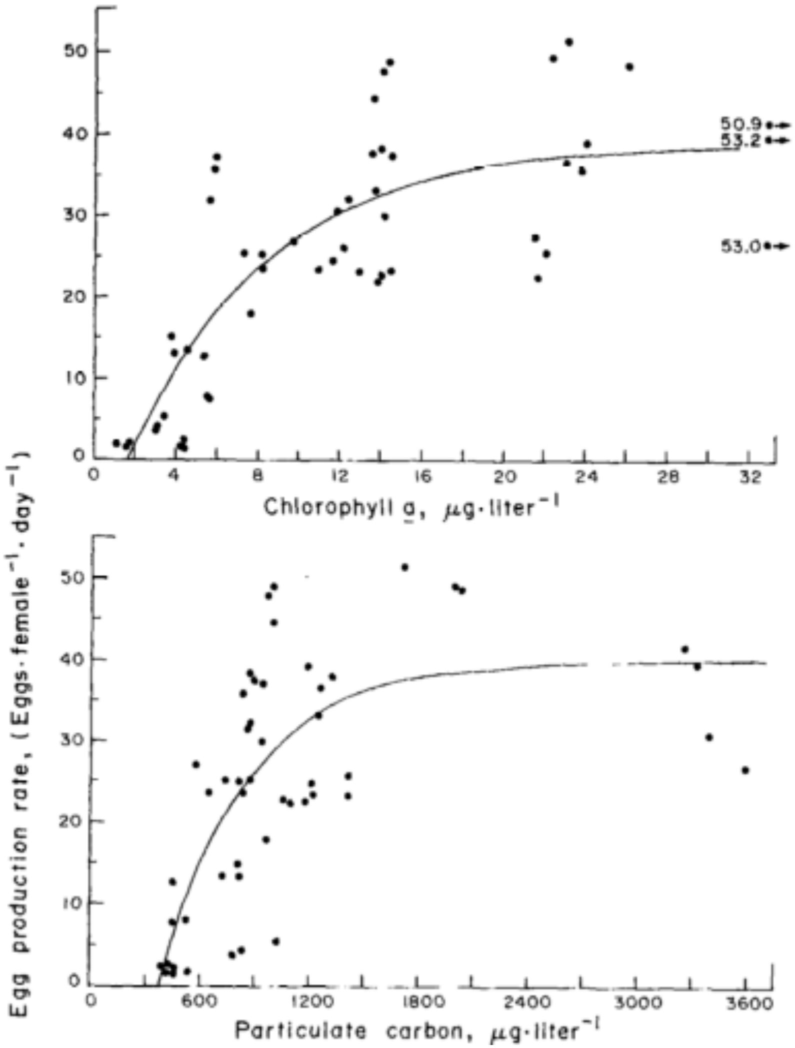


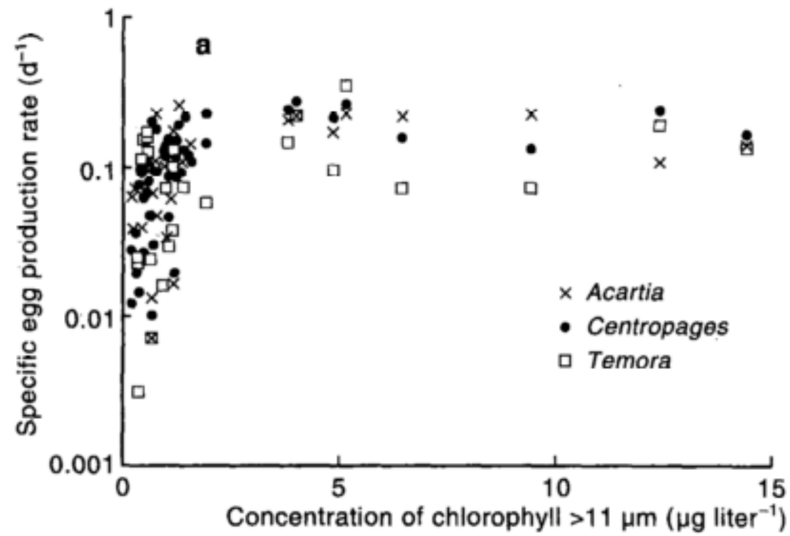
top predators
large sharks
smaller sharks
marlin
tuna
lancet fish
predators
squid
mackerel
filterers
lantern fish
amphipods
ocean sunfish
zooplankton
shrimp
copepods
pteropods
phytoplankton
dinoflagellates
diatoms

Introduction

Prey carbon biomass limits copepod production



Egg production of female copepods increases with phytoplankton biomass.



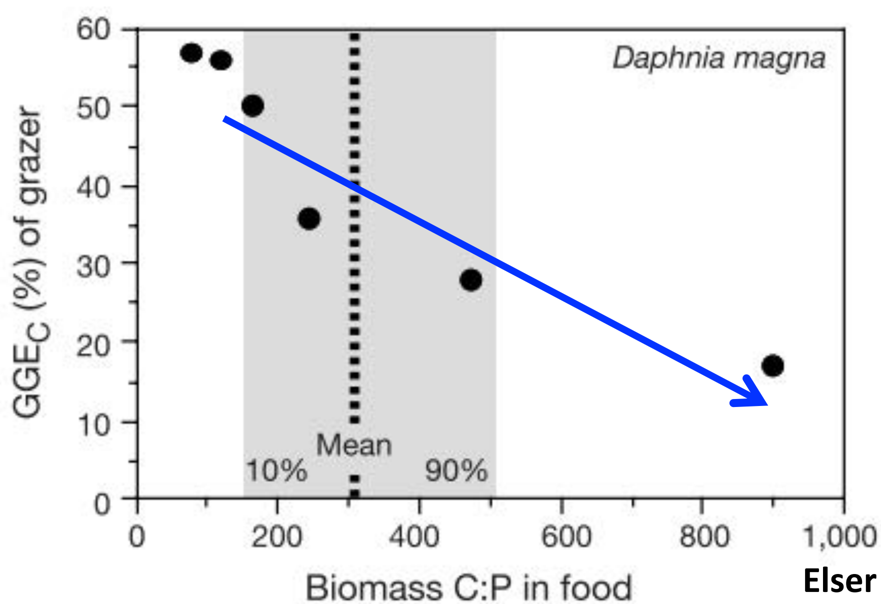
(Durbin et al. 1983)

(Kiørboe and Nielsen 1994)

Introduction

Prey stoichiometric imbalance also limits zooplankton growth

- Zooplankton have lower and less variable C:N and C:P ratio
  - Consumers have to excrete C and reduce growth efficiency when C:N/C:P is high



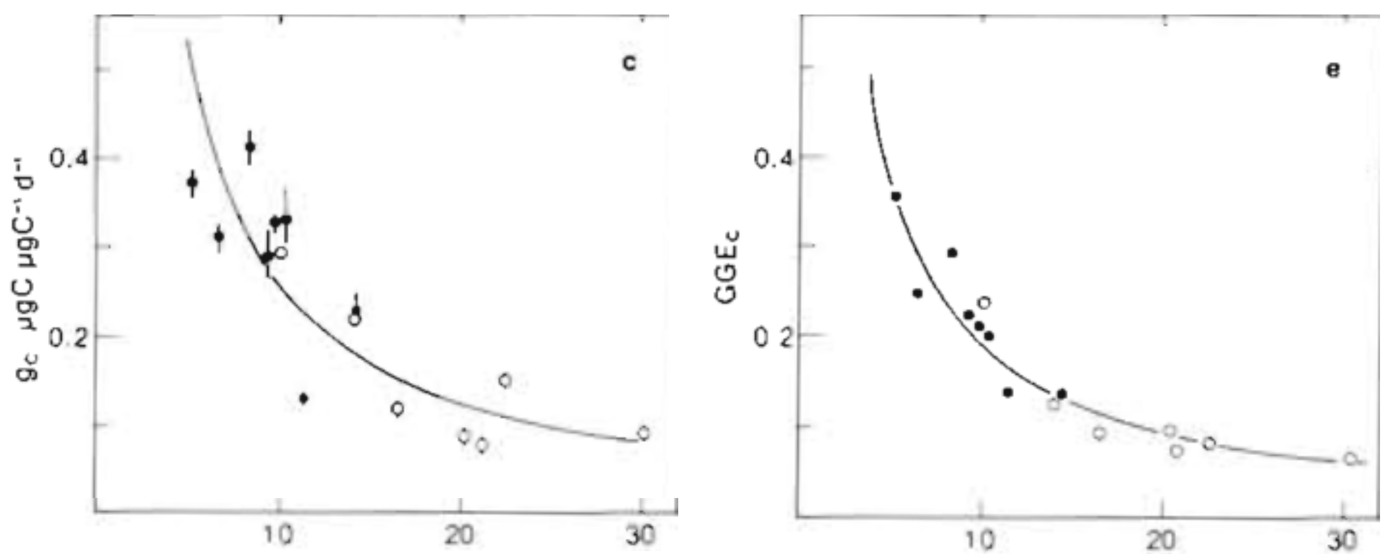
Elser et al. (2000)

Introduction

Prey stoichiometry influenced zooplankton production

- Balanced prey stoichiometry increases copepod production

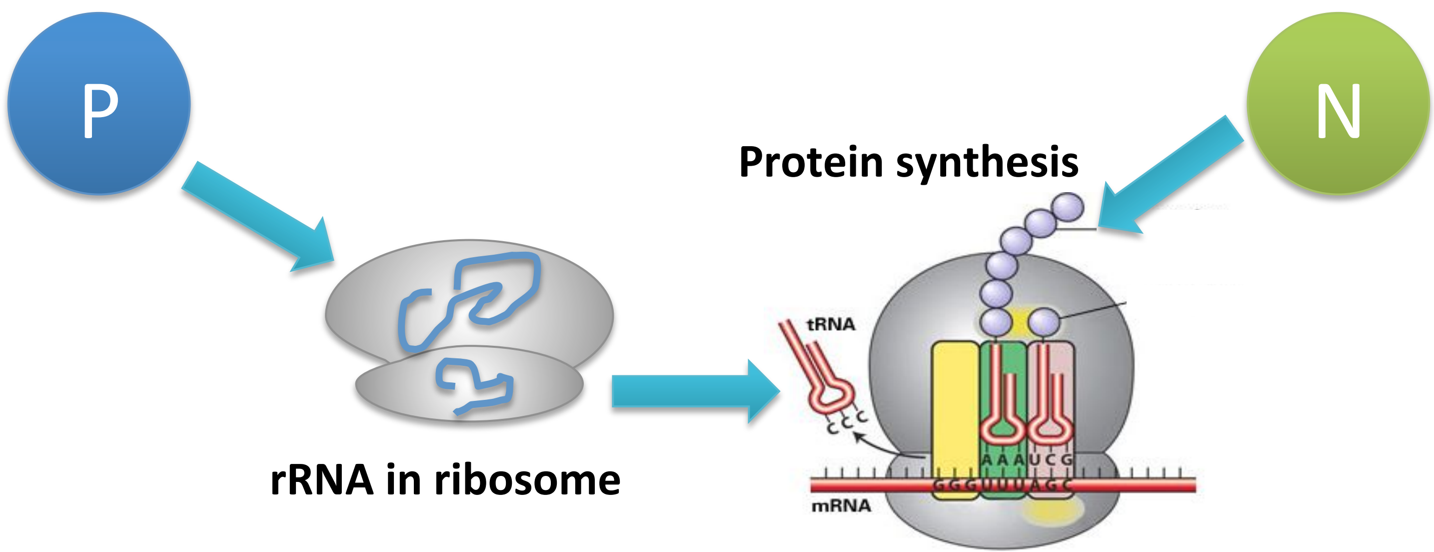
Egg production of *Acartia tonsa* feeding on diatom (Kiørboe 2007)



C:N of *Thalassiosira weissflogii*

N and P are essential to growth and biomass production

- N is the main element in protein structures
- P is essential to RNA production
  - Growth-rate hypothesis: P supply controls rRNA production and growth



Introduction

Phytoplankton and copepod composition v.s. copepod production

- Phytoplankton toxin and biochemical compositions may also influence zooplankton growth and both are taxon-specific
  (Viso and Marty 1993, Plumley 1997)

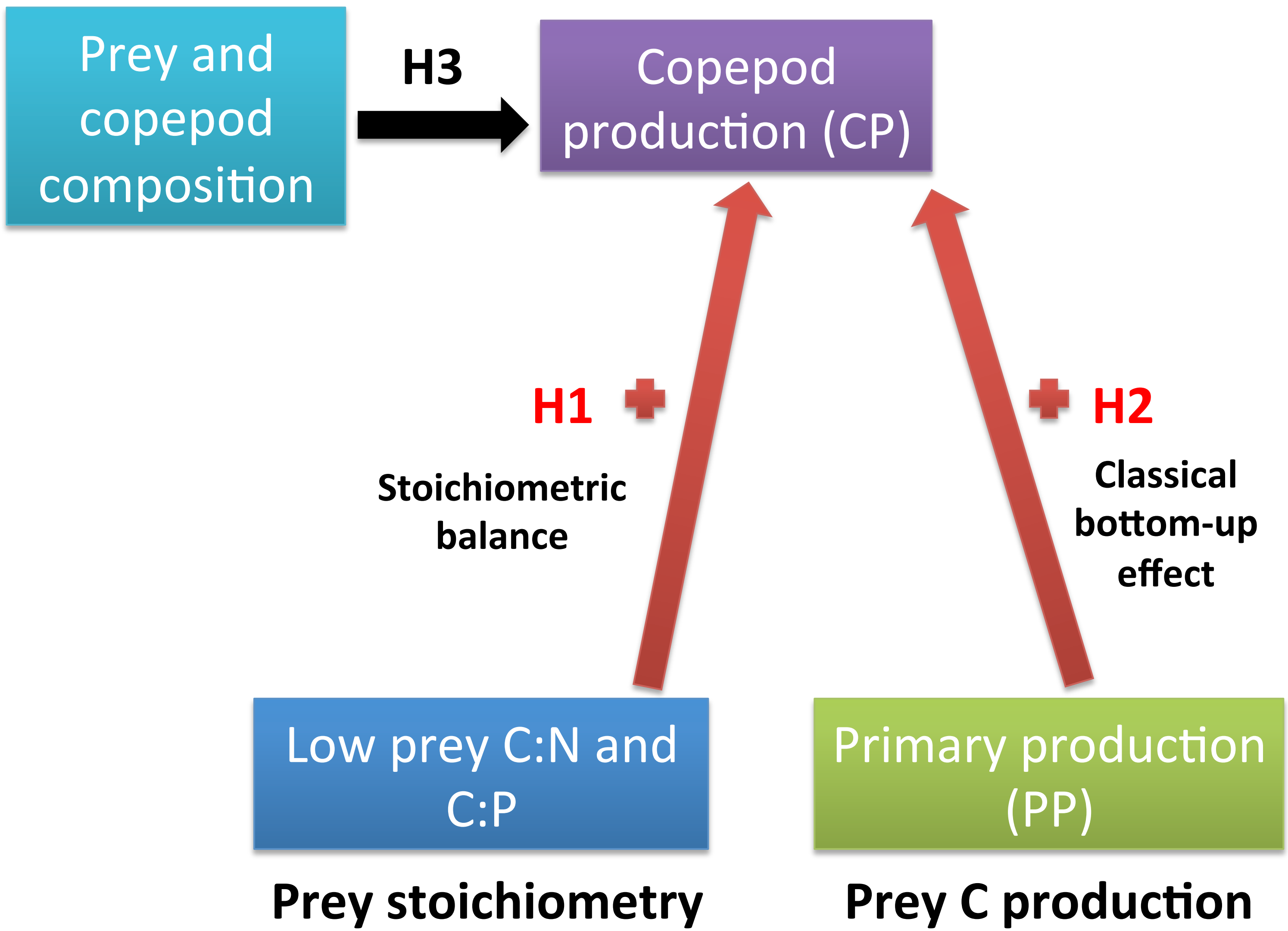
- Zooplankton of different taxa or life stages react distinctly to prey stoichiometry
  (Villar-Argaiz et al. 2002, Laspoumaderes et al. 2010)

Introduction

Knowledge gaps of copepod production in natural systems

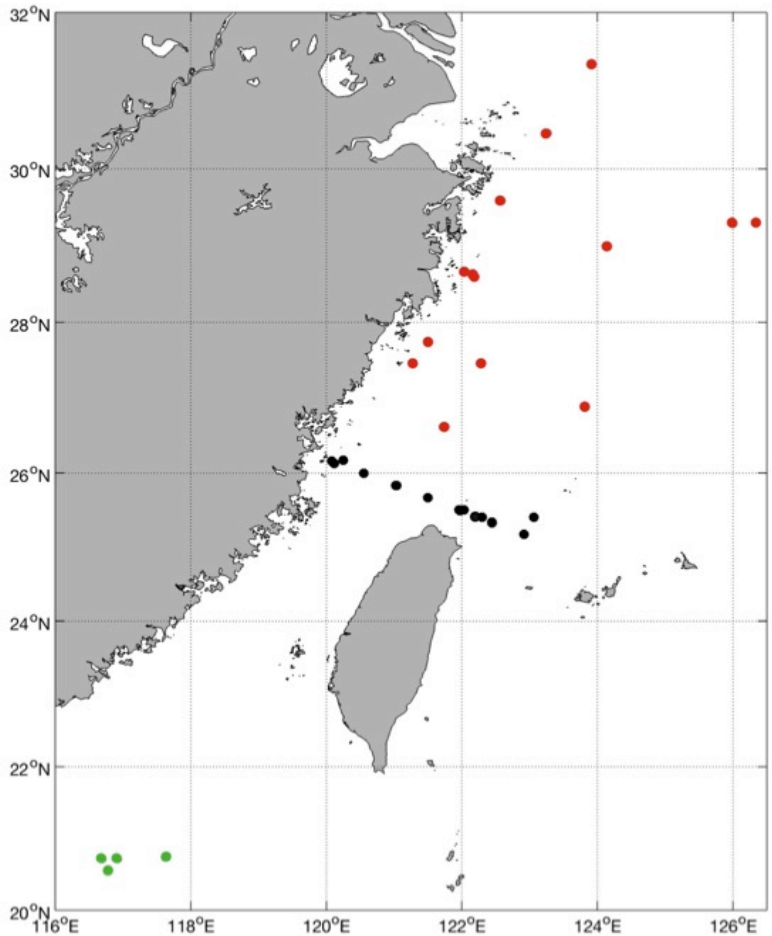
- Effects of stoichiometry on copepod production are mainly observed in lab incubations
  - ☐ Natural copepod and prey community
- Field observations usually based on egg production
  - ☐ Somatic growth

➔ Need *in situ* somatic growth measurements


Prey and copepod composition
H3
Copepod production (CP)
H1
Stoichiometric balance
H2
Classical bottom-up effect
Low prey C:N and C:P
Primary production (PP)
Prey stoichiometry
Prey C production

Materials and methods

Sampling area and targets



2009-2016, 54 experiments

Prey (phytoplankton)

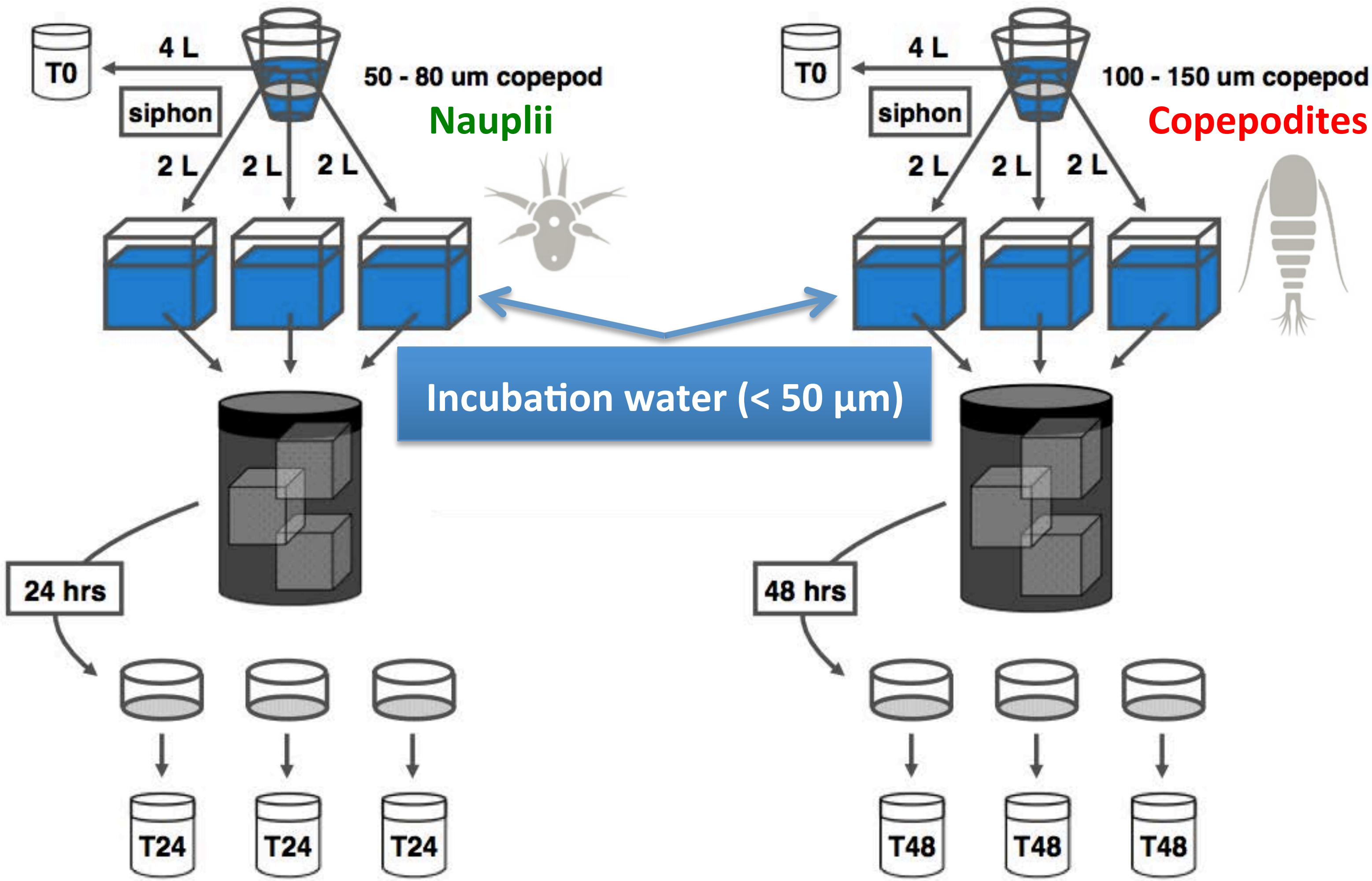
1. Prey stoichiometry: > 50 µm POM molar C:N:P ratio
2. PP
3. Phytoplankton composition

Copepod community

1. Copepodite and naupliar growth rate (GR)
2. Copepod community production (CP)
3. Copepod composition

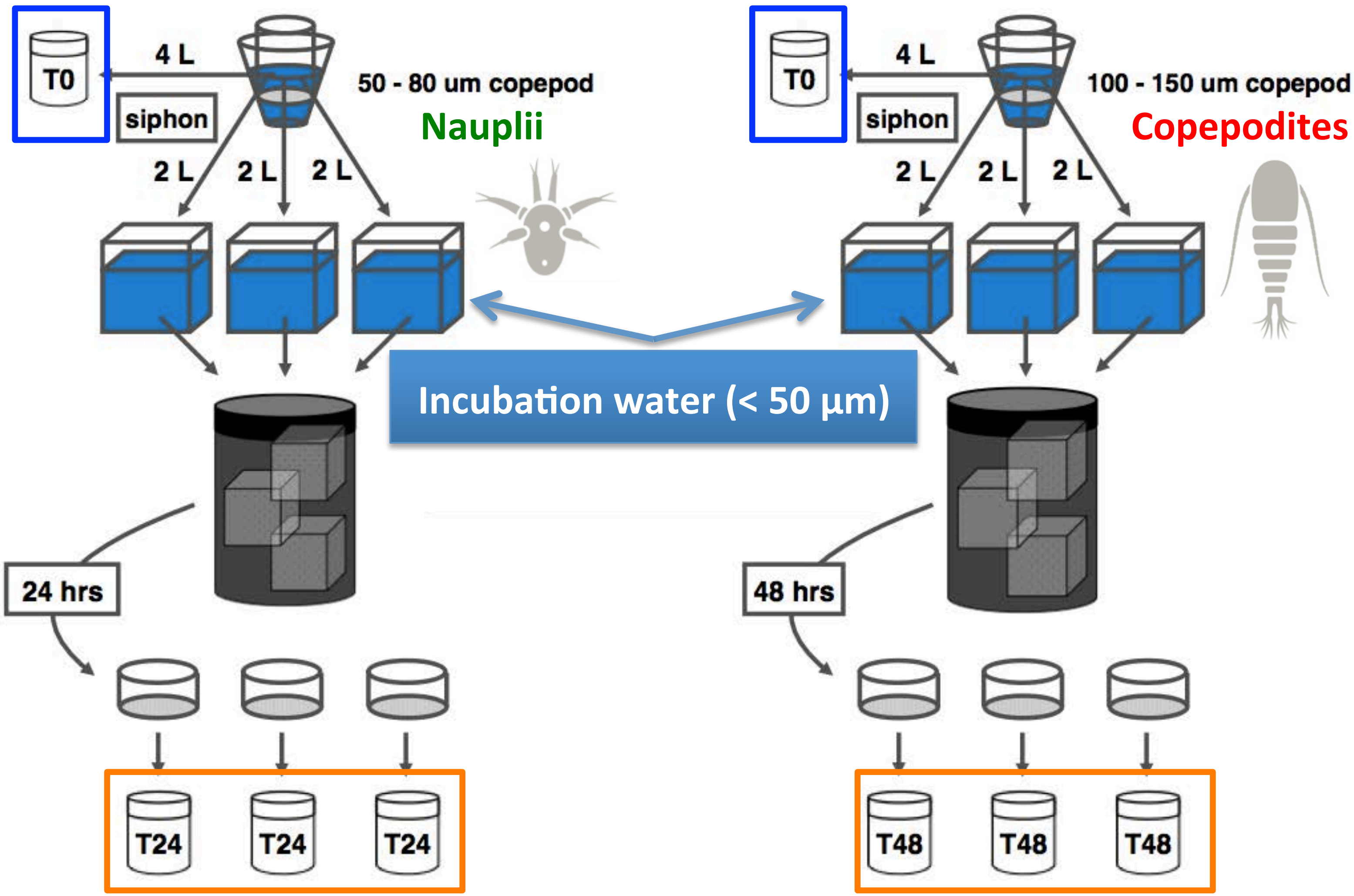
Materials and methods

In situ artificial cohort incubation



Materials and methods

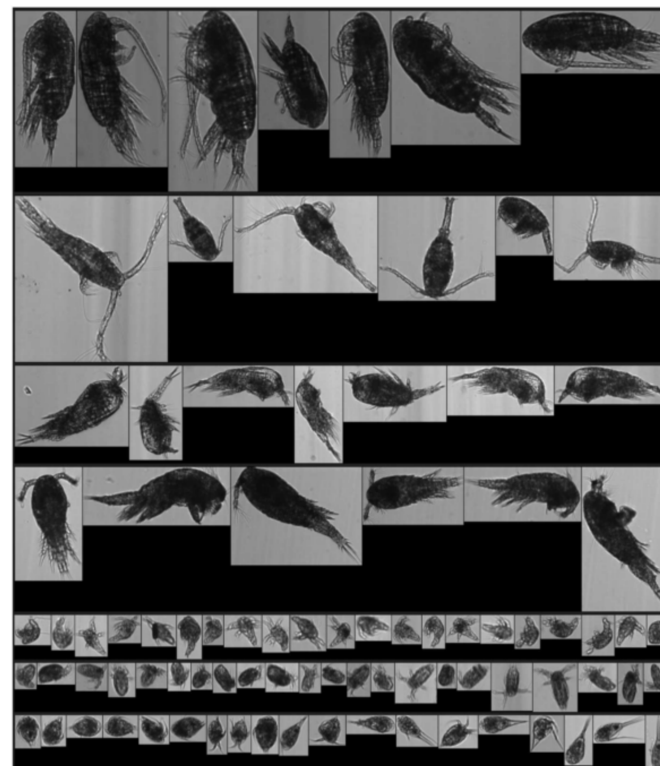
In situ artificial cohort incubation



Materials and methods

Copepod community growth rate

- Copepod body size distribution quantified by microscopes or FlowCam **(Lin et al. 2013; Wong et al. 2017)**



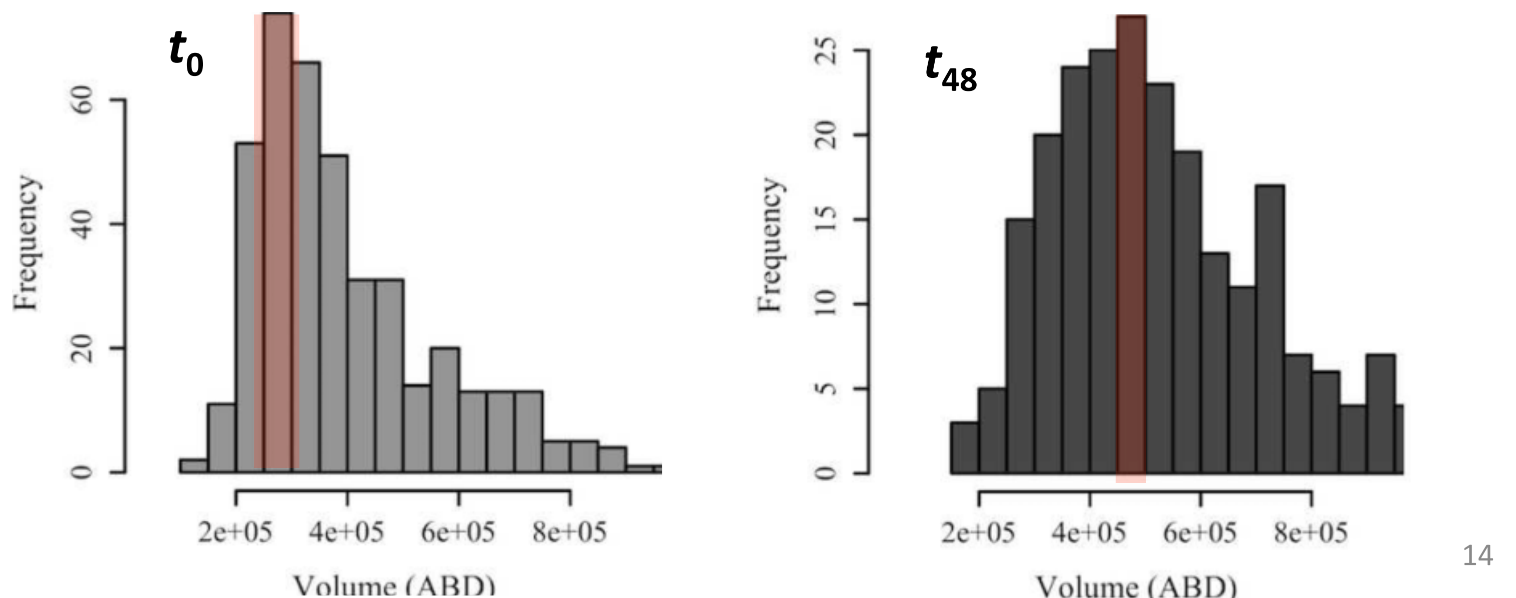
Materials and methods

Copepod community growth rate

- Group-specific growth rate: shift of the peak of copepod size distribution

(Lin et al. 2013)

$$GR_i = \ln\left(\frac{W_T}{W_0}\right) / T$$



Materials and methods

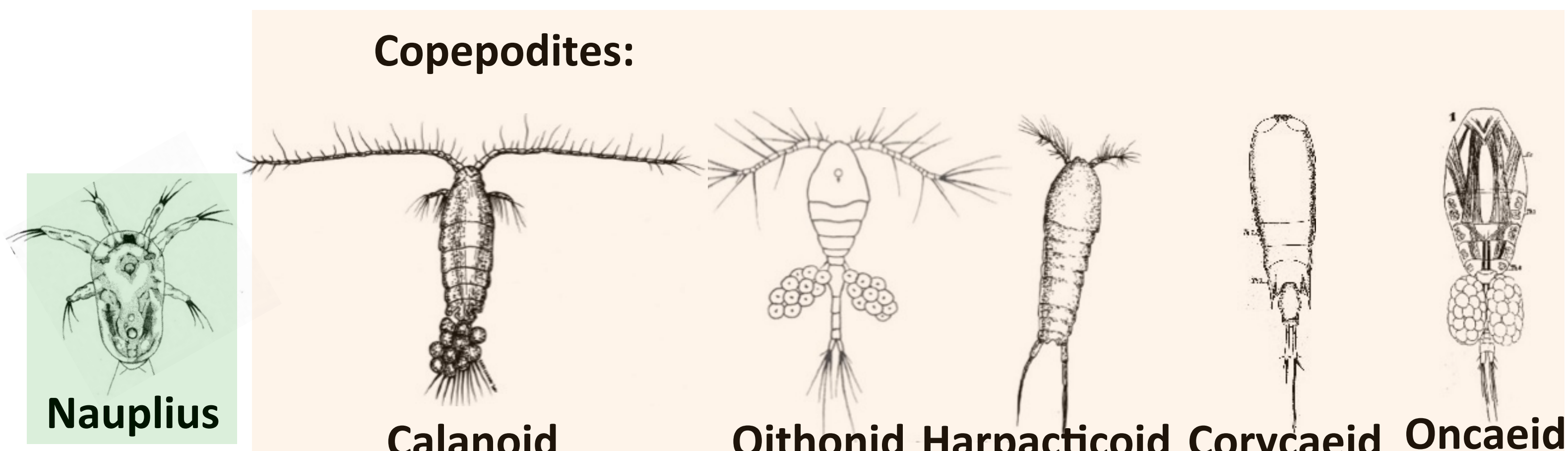
Copepod community growth rate

- Abundance of each group is quantified by counting individuals from 50 µm Norpac net

$$B_i = N_i m_i$$

m_i: mean body mass of group *i* at t_0

$$\text{Weighted-mean GR} = \frac{\sum \mathrm{GR}_i \times B_i}{\sum B_i}$$



Materials and methods

Community production of copepod and phytoplankton

- Copepod production (CP)

$$\mathrm{CP}_i = B_i(e^{\mathrm{GR}_i} - 1)$$ Group-specific CP

$$\mathrm{CP} = \sum_i \mathrm{CP}_i$$ Community CP

- Primary production (PP)

^{14}C assimilation method

(Parsons et al. 1984)

Phytoplankton stoichiometry

- POM C:N:P is measured as prey stoichiometry
  - C and N content: Elemental analyzer (EA)
  - P content: wet digestion with nitric acid followed by ascorbic-Mo spectrophotometric method

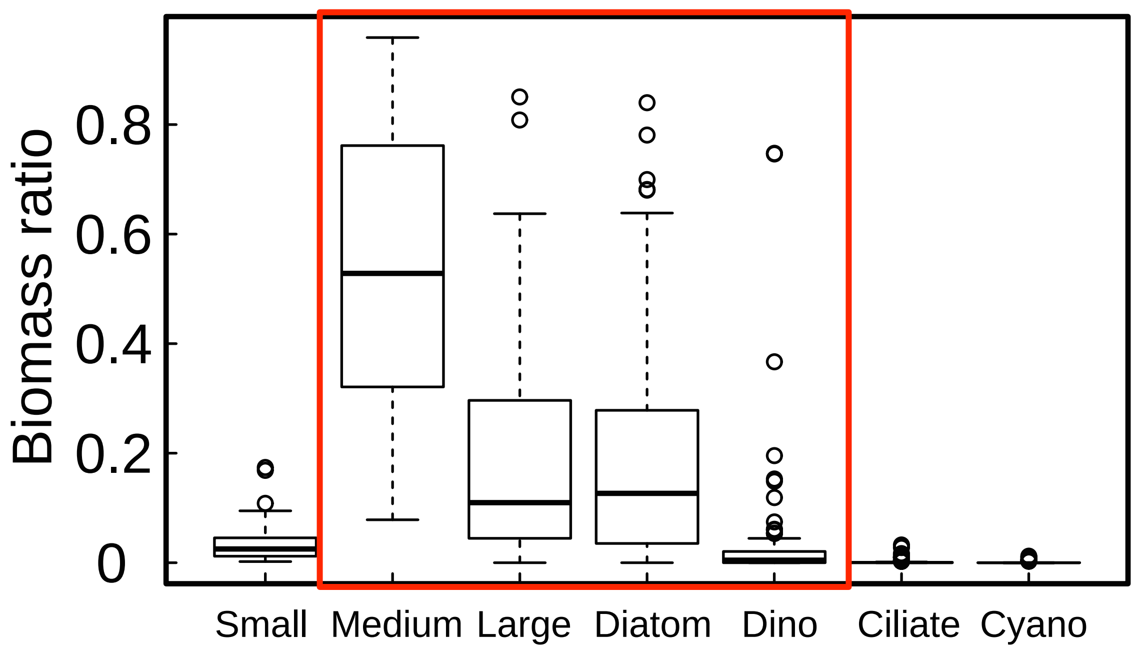
5 L water filtered through 50 μm sieve →  → Prey (mainly phytoplankton) C:N:P

POM on GF/F filter

Materials and methods

Phytoplankton composition quantified by FlowCam

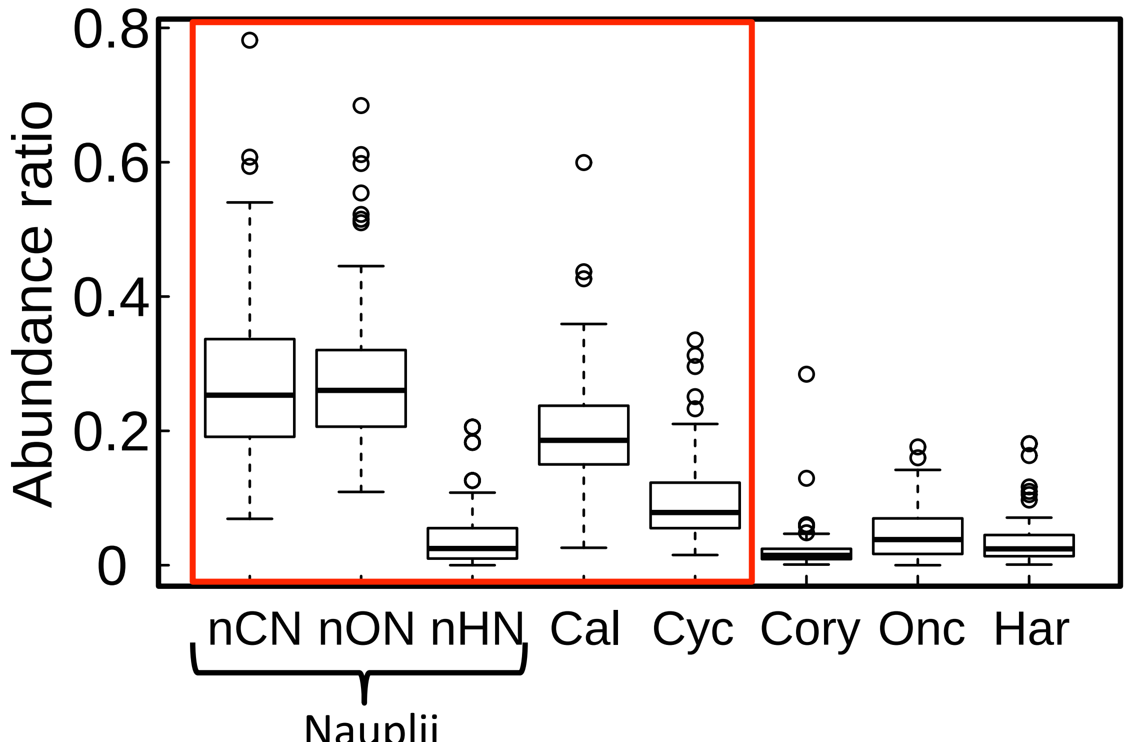
- Phytoplankton biomass: sea water collected in euphotic zone
  - Biovolume calculated from ABD as the index of biomass



Materials and methods

Copepod composition quantified by microscopes

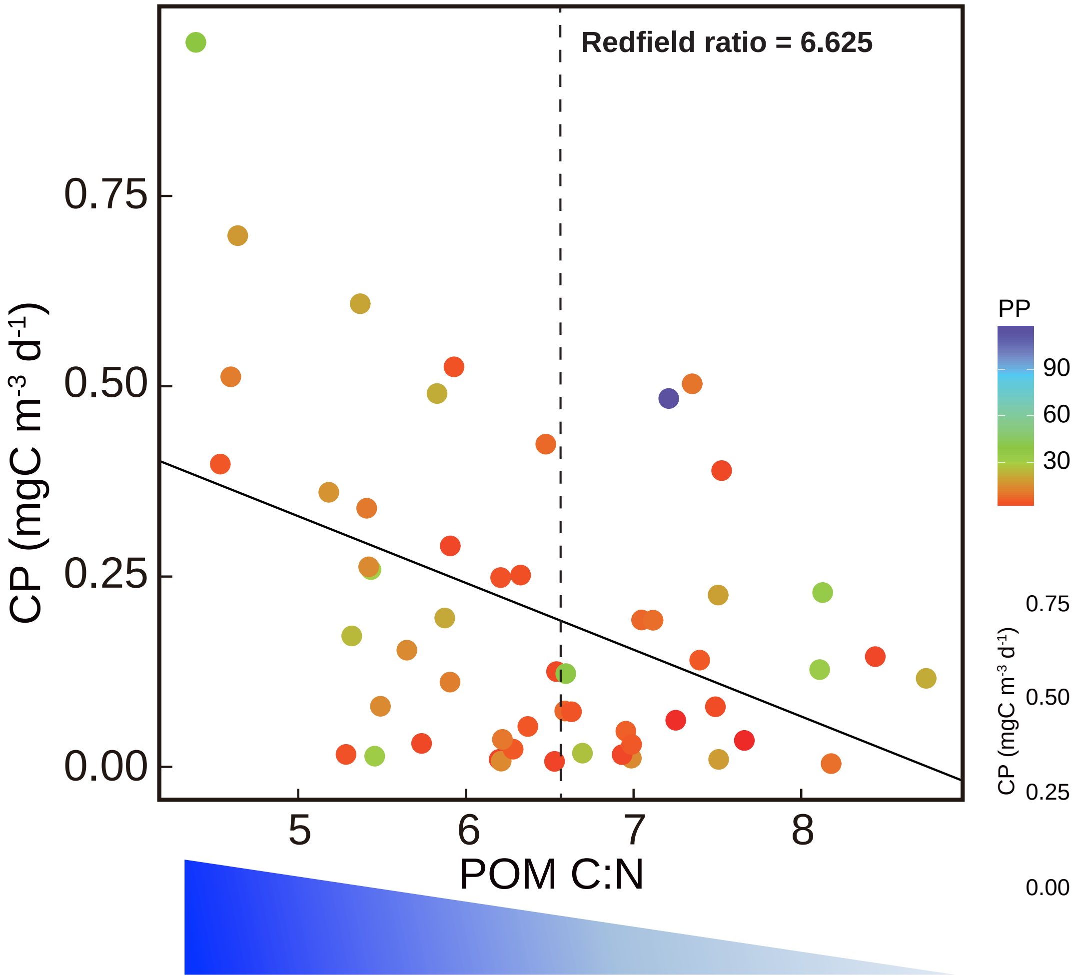
- Zooplankton abundance: copepods collected by 50 μm mesh Norpac net



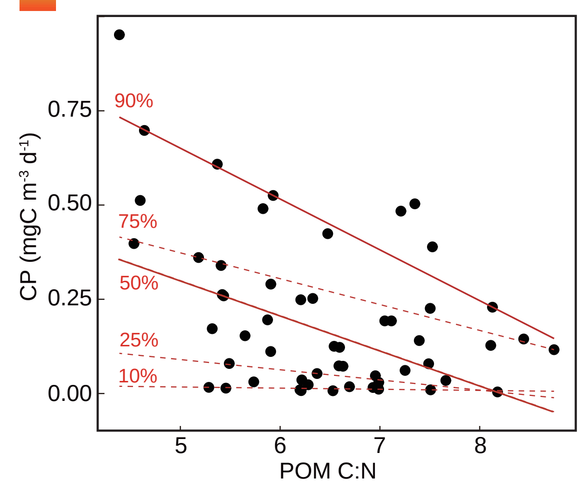
Results

Copepod production decreases with prey C:N ratio

$y = -0.088\,x + 0.768$, $R^2 = 0.190$, $p = 0.001$

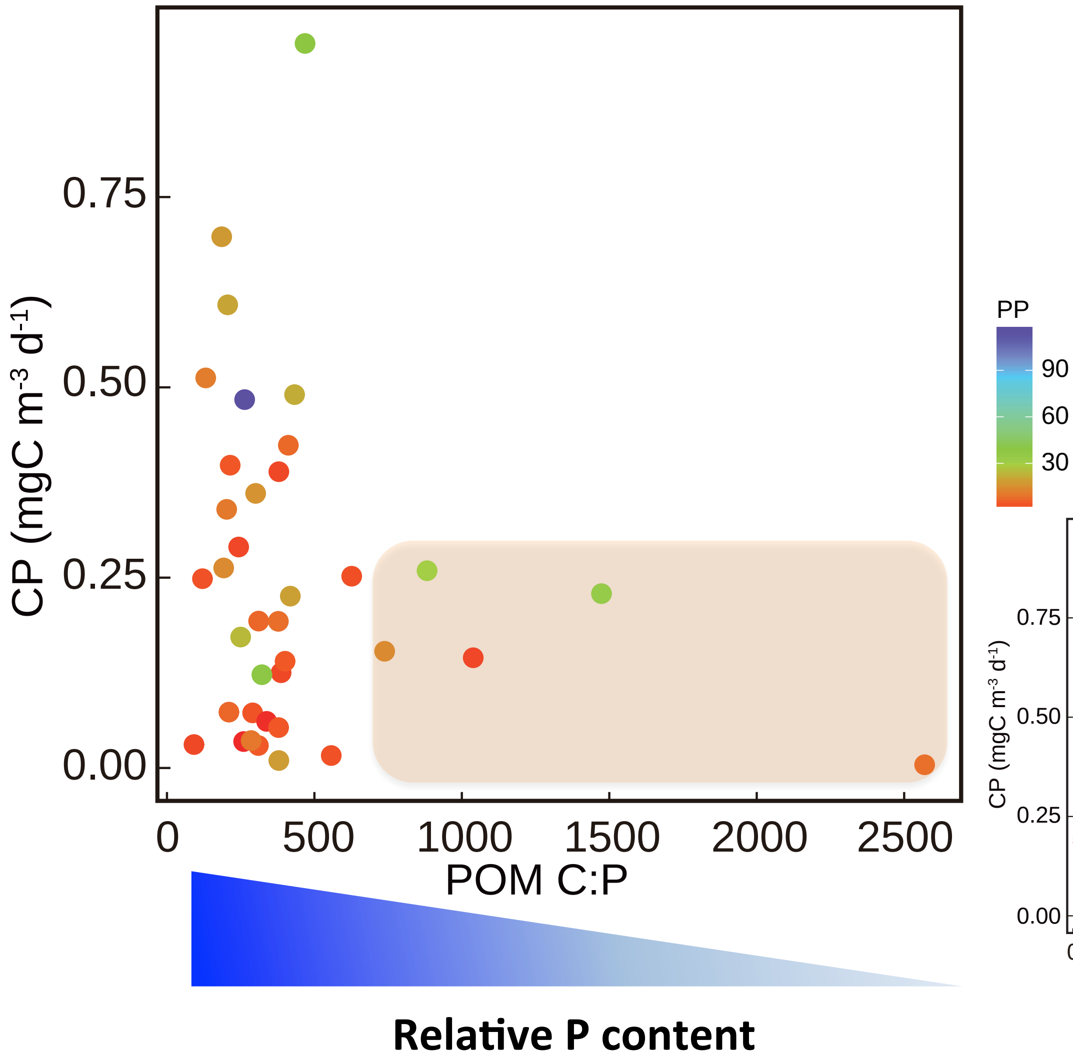


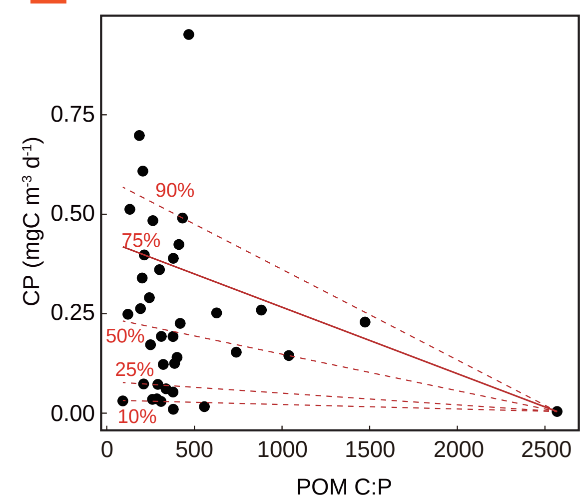
Relative N content



Results

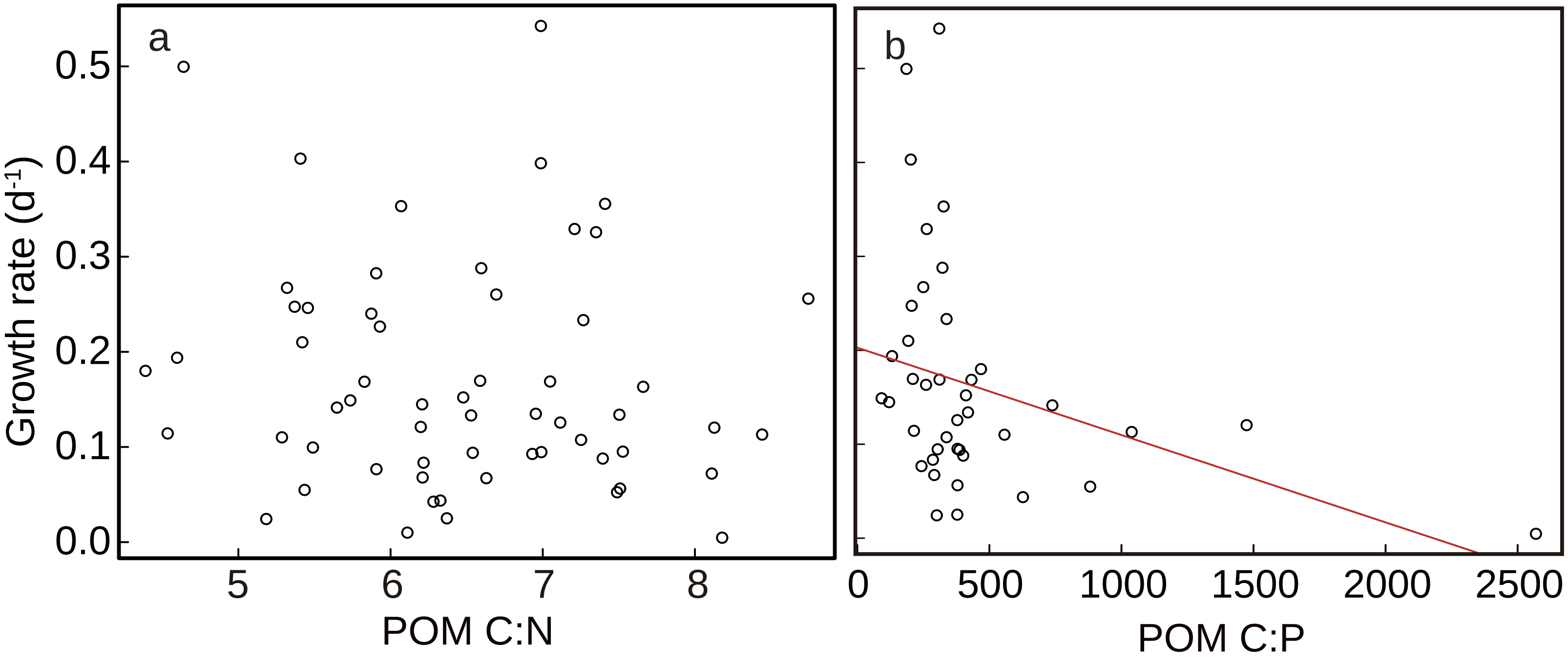
Copepod production lowers when prey C:P ratio is high





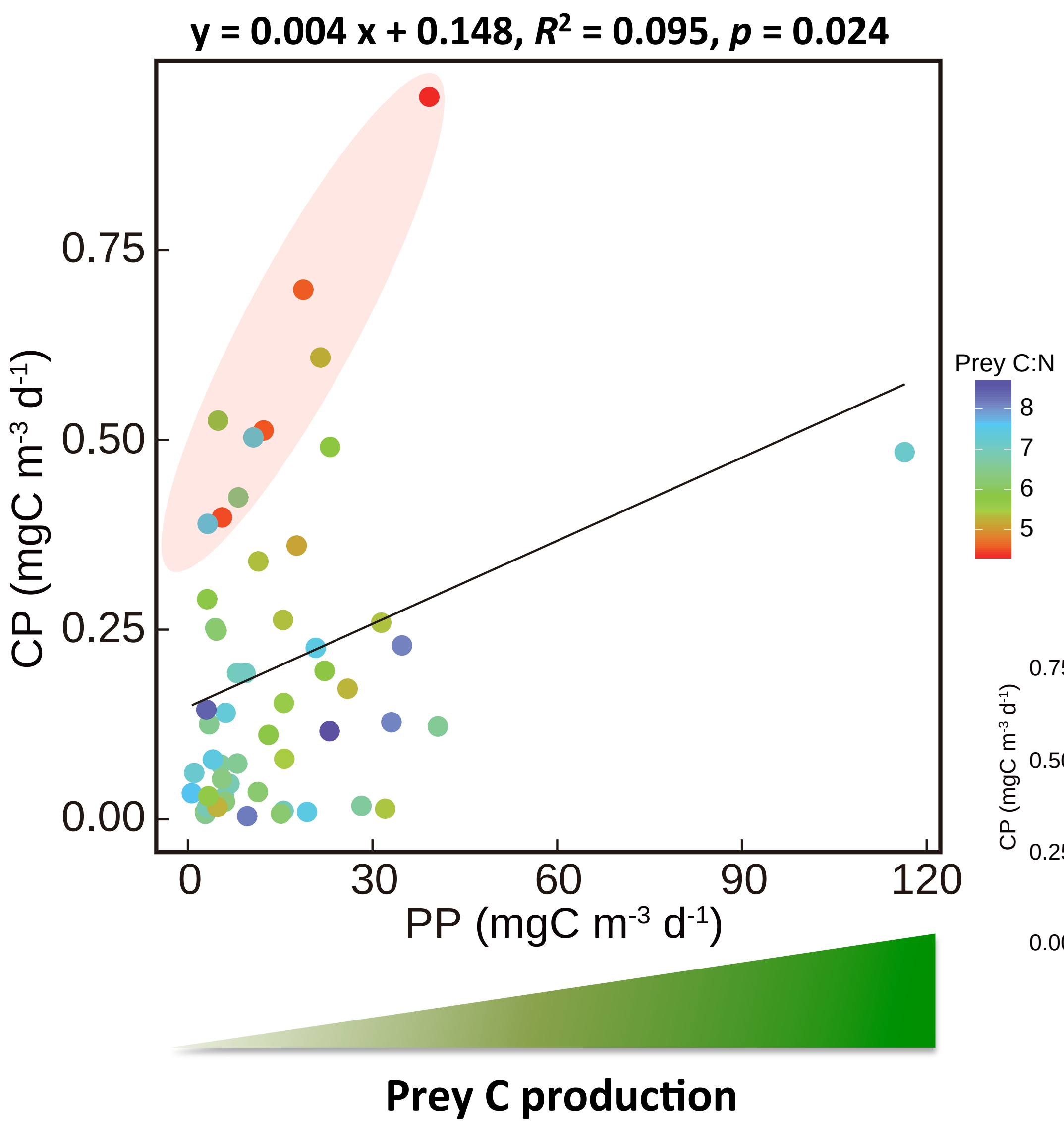
Results

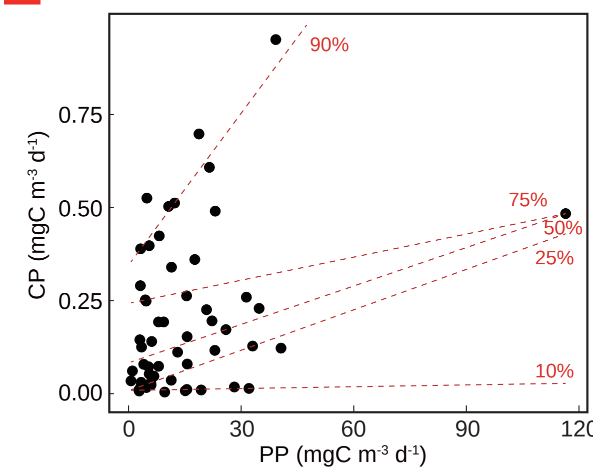
Copepod growth lowers when prey C:P ratio is high



Results

Copepod production increases weakly with PP





Results

Phyto- and copepod composition influence copepod production

- Full model

Prey C:N, PP, phytoplankton and copepod composition

- Most parsimonious model by AIC

$CP = -0.107 \text{ Prey C:N} + 0.473 R_{DinoB} - 1.199 R_{Cyc\#}$

$R^2 = 0.183$, $P = 0.0216$

Relative importance:
Prey C:N (65.3%) > $R_{Cyc\#}$ (18.4%) > R_{DinoB} (16.3%)

Discussion

Copepod production is critically influenced by prey stoichiometry

☑ Copepod production is higher when prey C:N is low
- ◆ N is the element that supports copepod biomass production

☐ Copepod production is higher when prey C:P is low, but regression is not significant
- ◆ Growth rate is lower when P is limited
- ◆ Even when prey P is rich, other resources (e.g. N content) may limit biomass production

Discussion

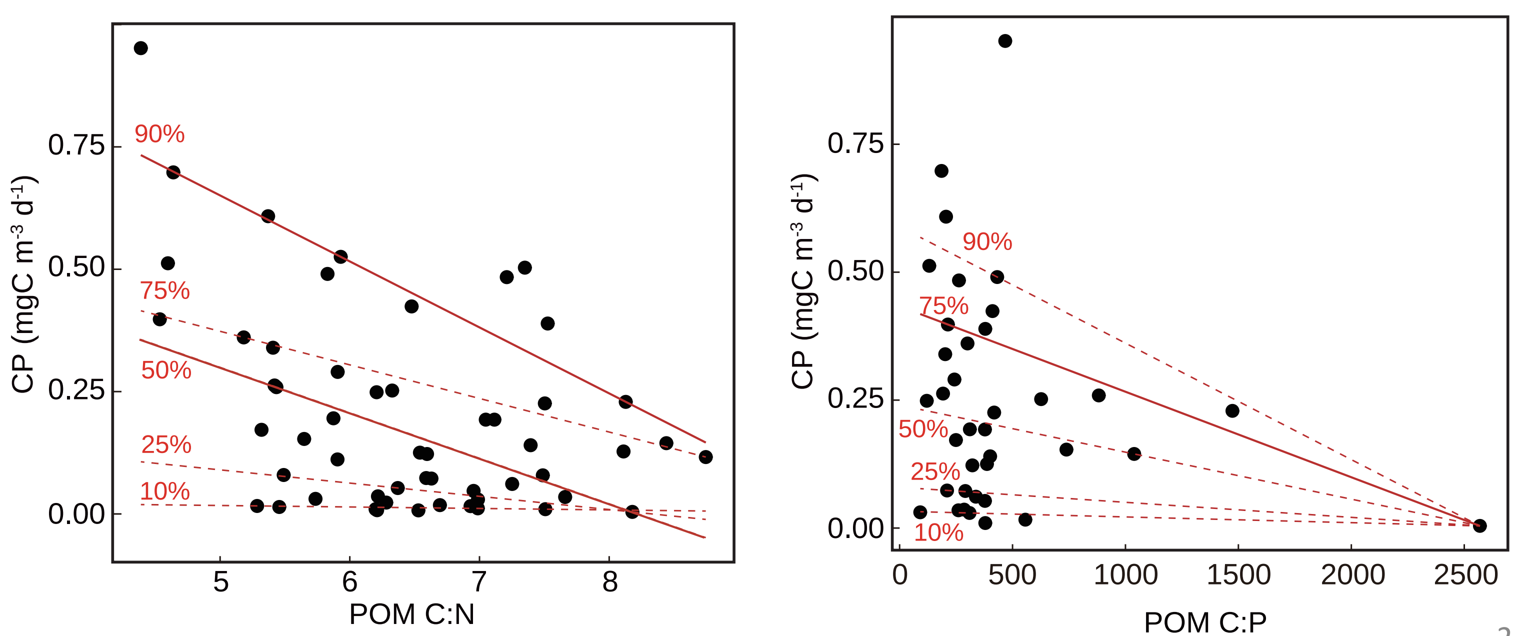
High copepod production may occur with low PP

- Copepod production may be high when PP is low, if prey C:N or C:P is small
  - Balanced prey stoichiometry improves the assimilation efficiency and thus biomass production

Discussion

High prey stoichiometric quality is not necessarily linked with high CP

- High CP may not be supported when prey C:N or C:P ratios are low
  - Essential fatty acids **(Ferrão-Filho et al. 2003)**



Discussion

Phytoplankton and copepod community affect CP

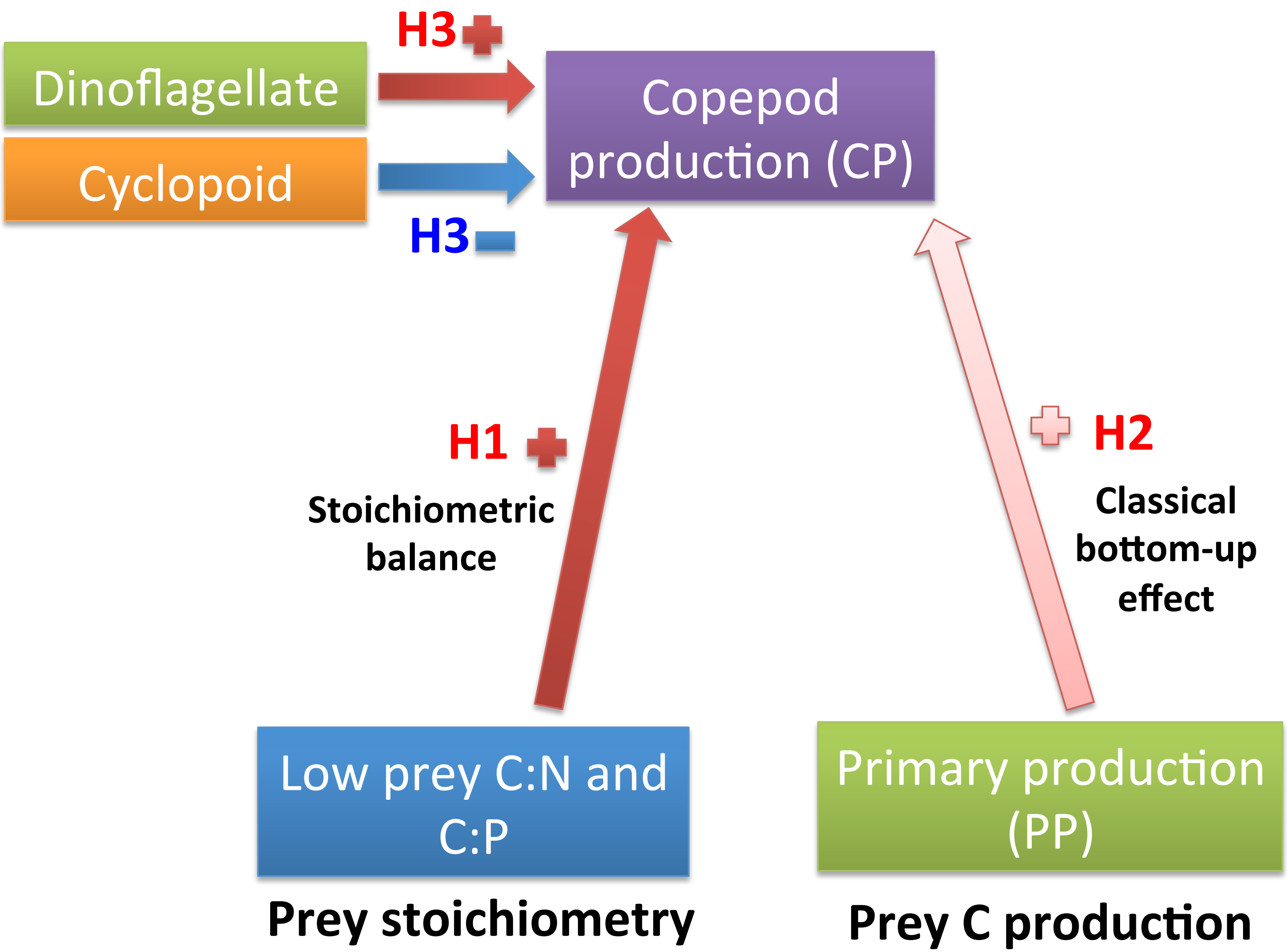
- Copepods consuming a mixture of dinoflagellates and microzooplankton grow better than feeding on a diatom-dominant diet

  (Nejstgaard et al., 2001)

- Lower growth rates of cyclopoid relative to calanoid copepodites

  (Hirst and Lampitt, 1998; Lin et al., 2013)

Take home message: What influences copepod production?



Thanks for your attention

All comments are welcomed