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Changing food quality

consequences for food web structure and functioning

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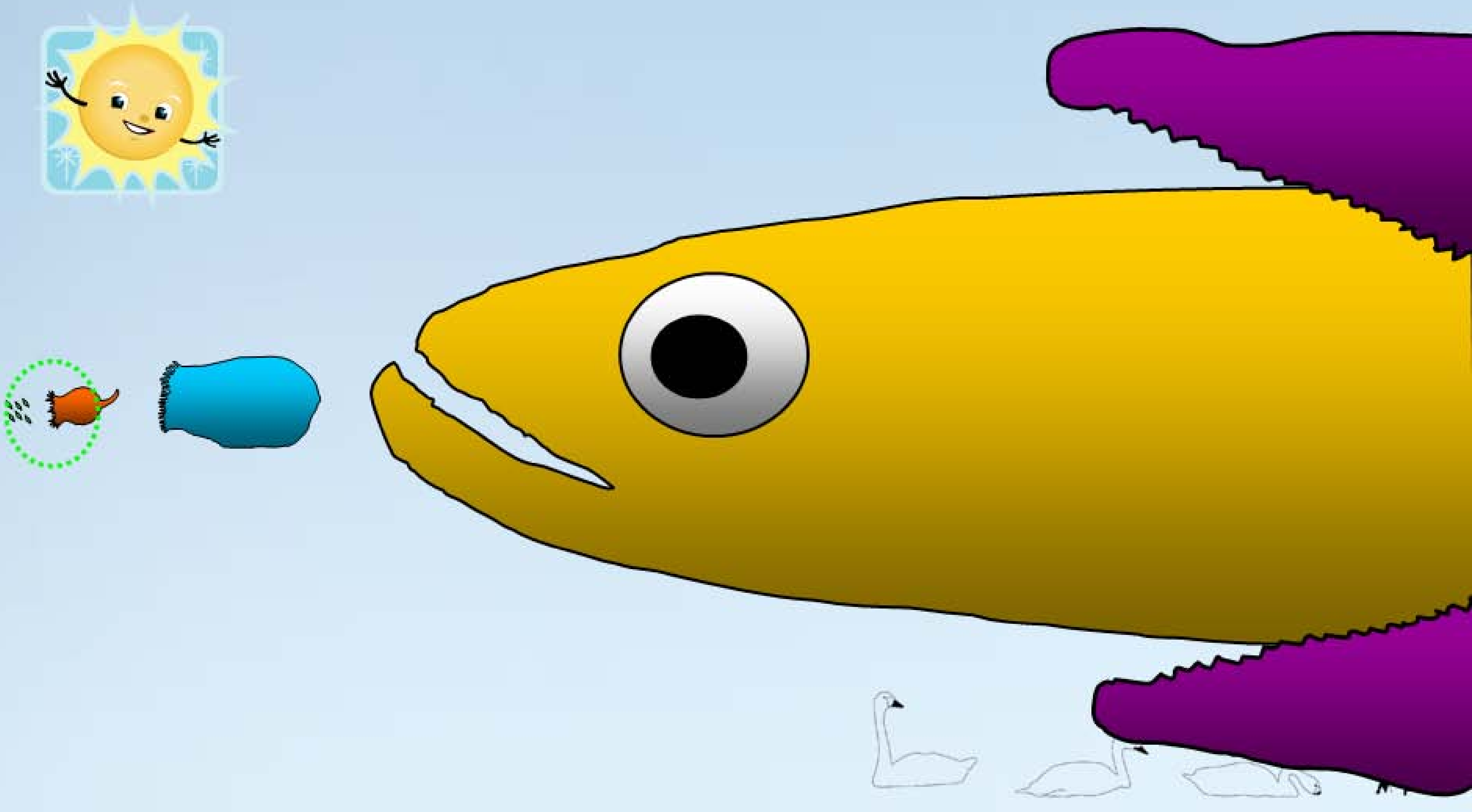
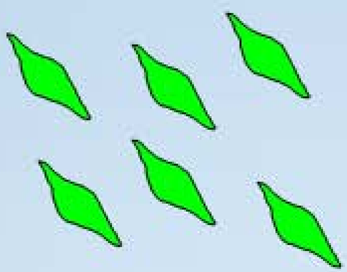
Phytoplankton at the base of the pelagic food web



Importance of phytoplankton food quality for zooplankton populations in food webs



- Ontogeny and survival
  - Food quality may be inferior or superior
- Competition and coexistence
  - Superior and inferior competitors occupy certain niches
- Population persistence
  - Quality may determine the magnitude of population cycles and whether minimum densities can be attained

two topics related to phytoplankton food quality

1. Biotic (trophic) interactions
   - eating and being eaten
     - Inducible defences
     - Mediated by infochemicals
     - Phytoplankton morphology
     - Pre-ingestion food quality
2. Abiotic interactions
   - climate change
     - Altering chemical environment
     - Phytoplankton chemical composition (stoichiometry)
     - Post-ingestion food quality

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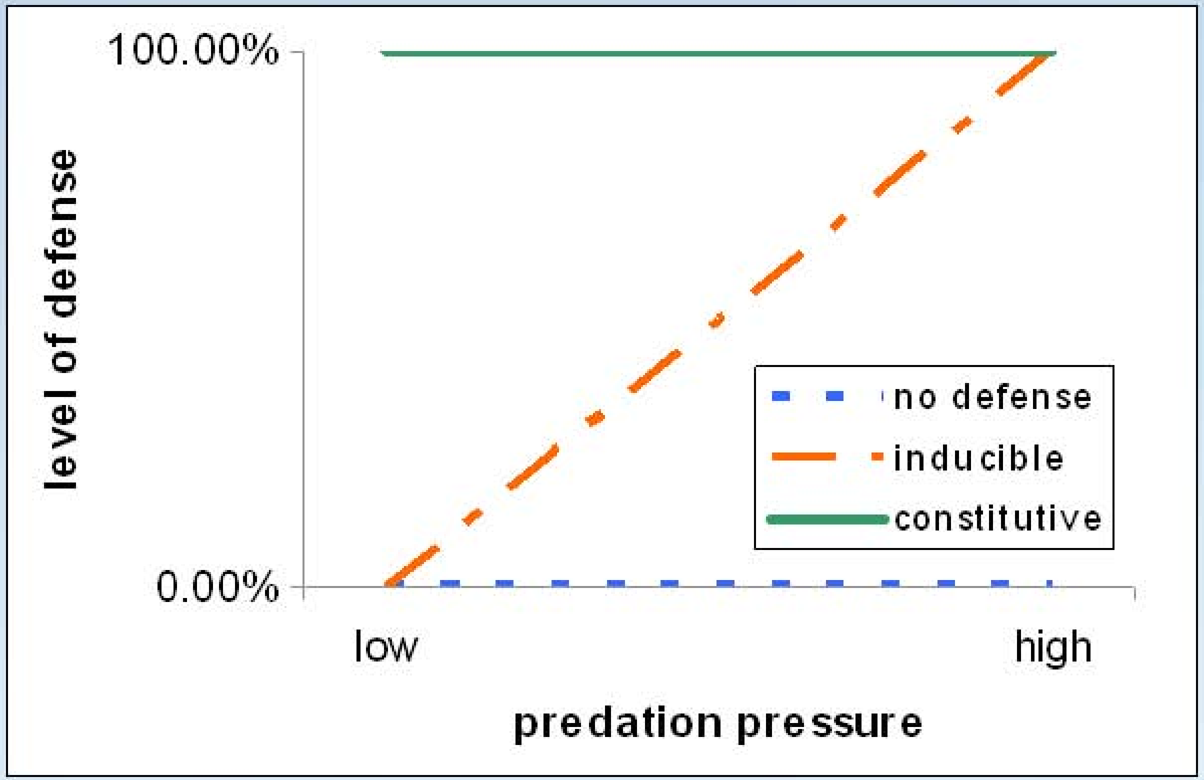
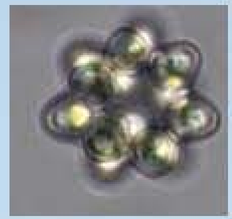
1. Biotic interactions: inducible defences

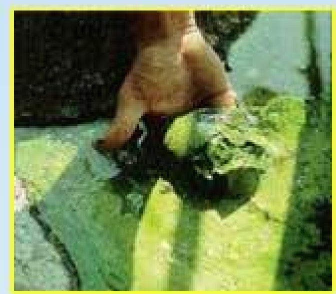


Inducible defences in phytoplankton

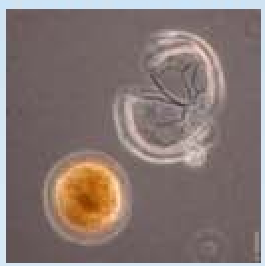
- Morphological
  - Colonies, mucus, spines



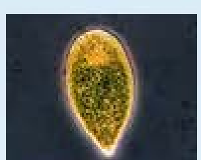
- Chemical
  - Deterrents, toxins (*Microcystis*)


- Resting cysts
  - *Alexandrium ostenfeldii*

- Behaviour (recruitment *Gonyostomum semen*)



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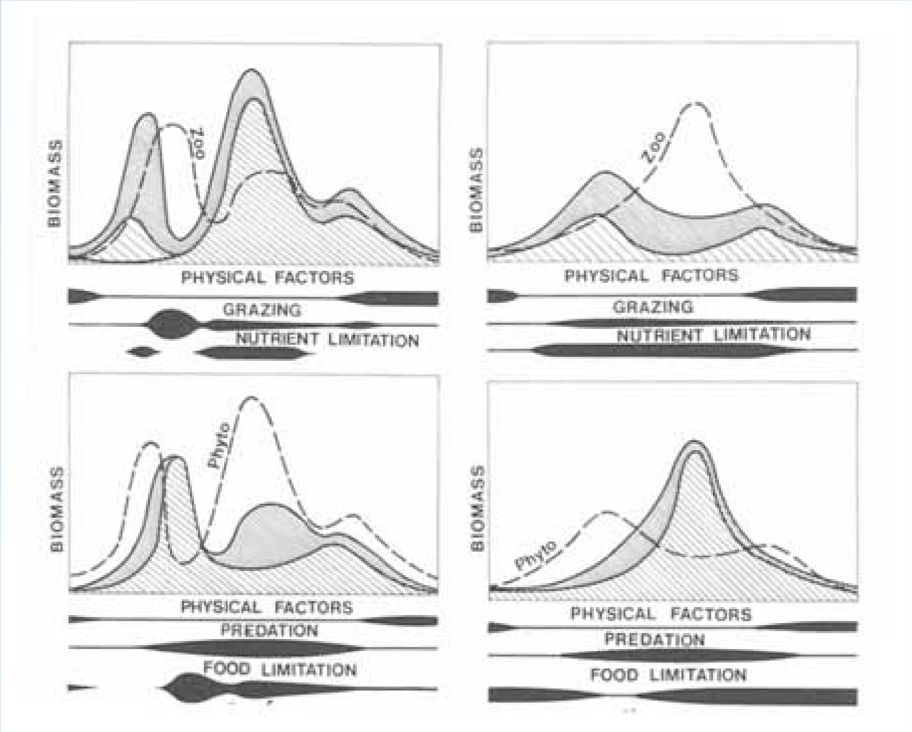
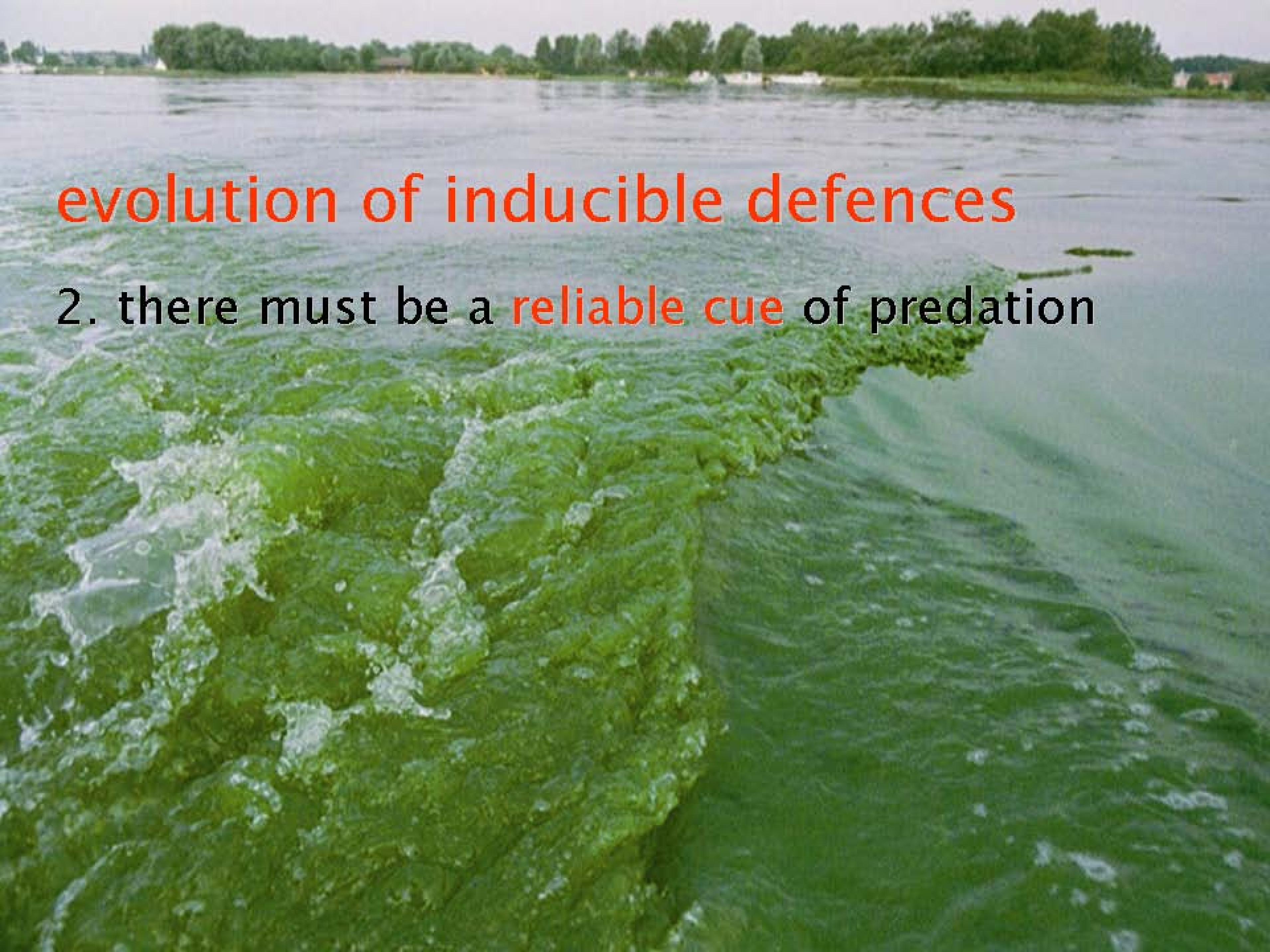
evolution of inducible defences

1. form of phenotypic plasticity that develops under variable predation

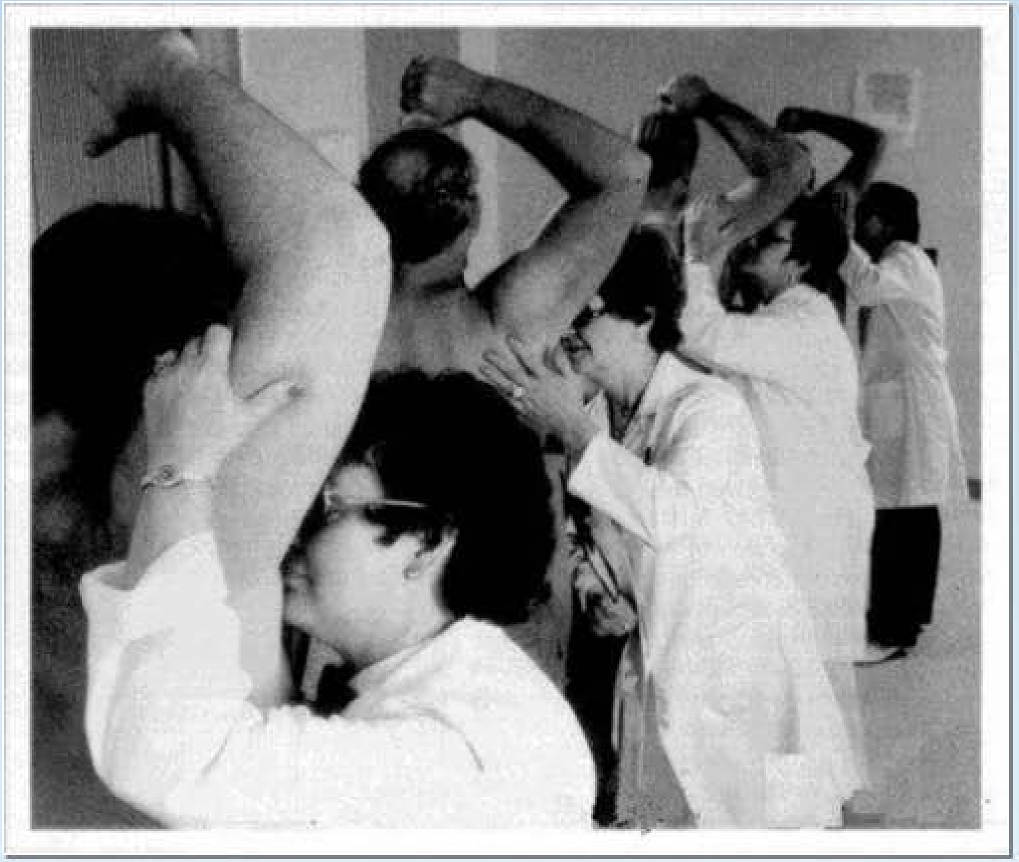


evolution of inducible defences

2. there must be a reliable cue of predation



Information chemicals (infochemicals)



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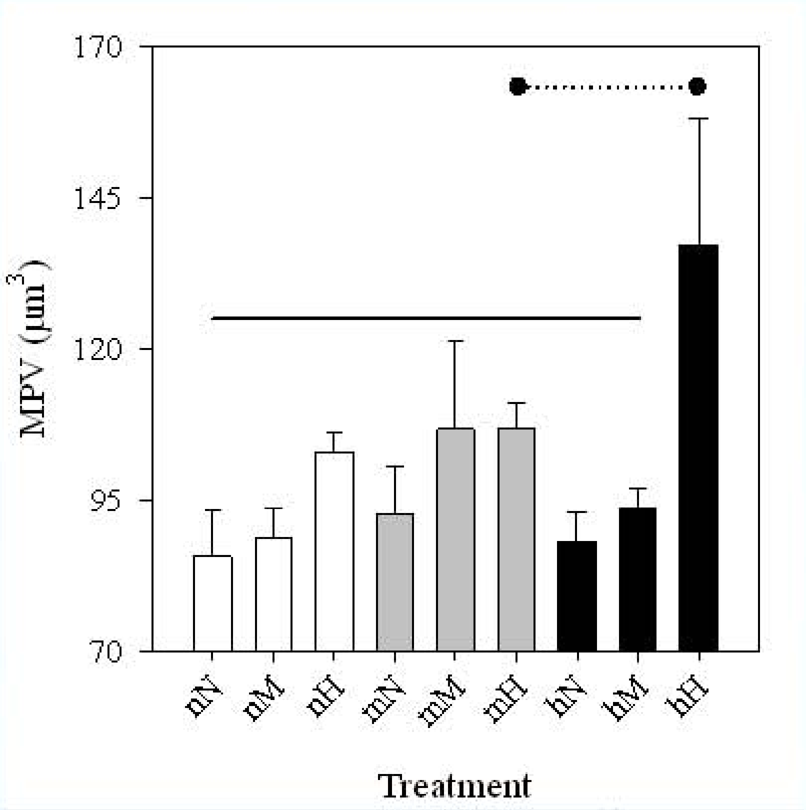
evolution of inducible defences

- their must be a reliable cue of predation



Verschoor, Zadereev, Mooij (2007). Limnol. Oceanogr. In press [52(5)]

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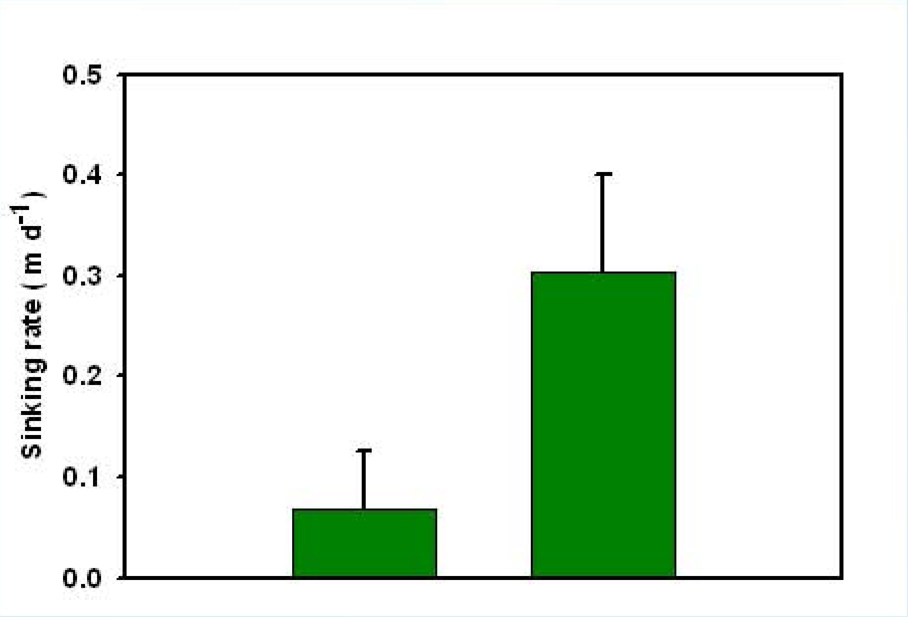
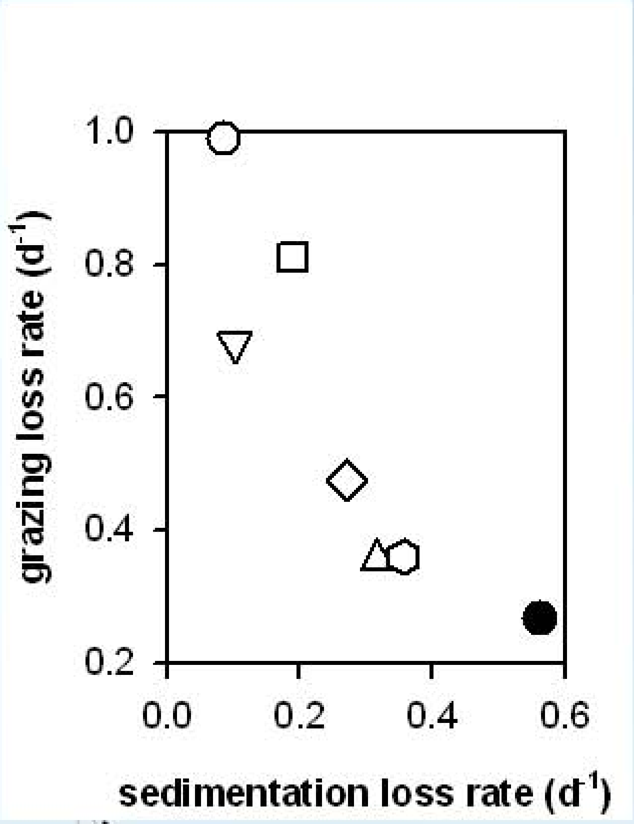
evolution of inducible defences

- their should be fitness costs associated with defences (trade-off)



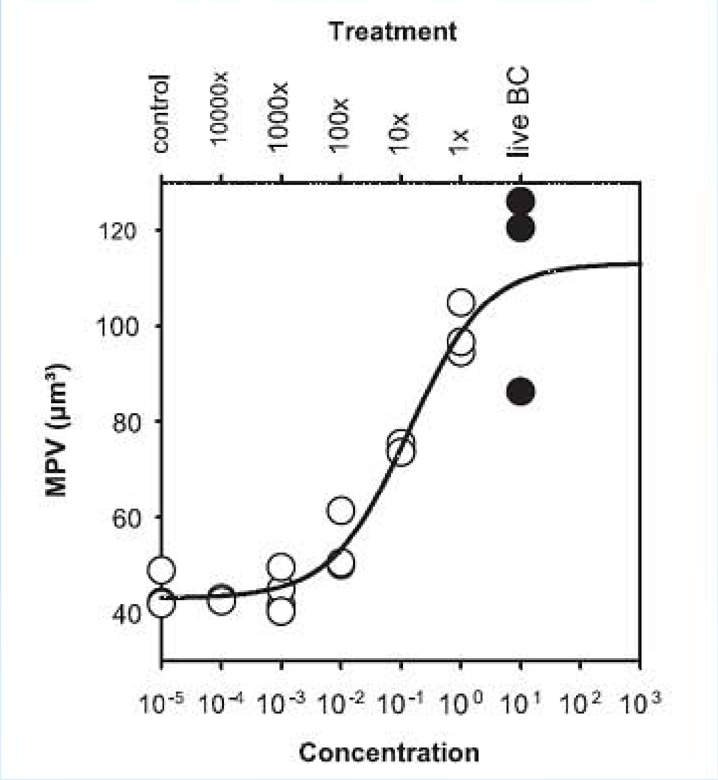
Lürling & Van Donk (2000). Oikos 88:111-8



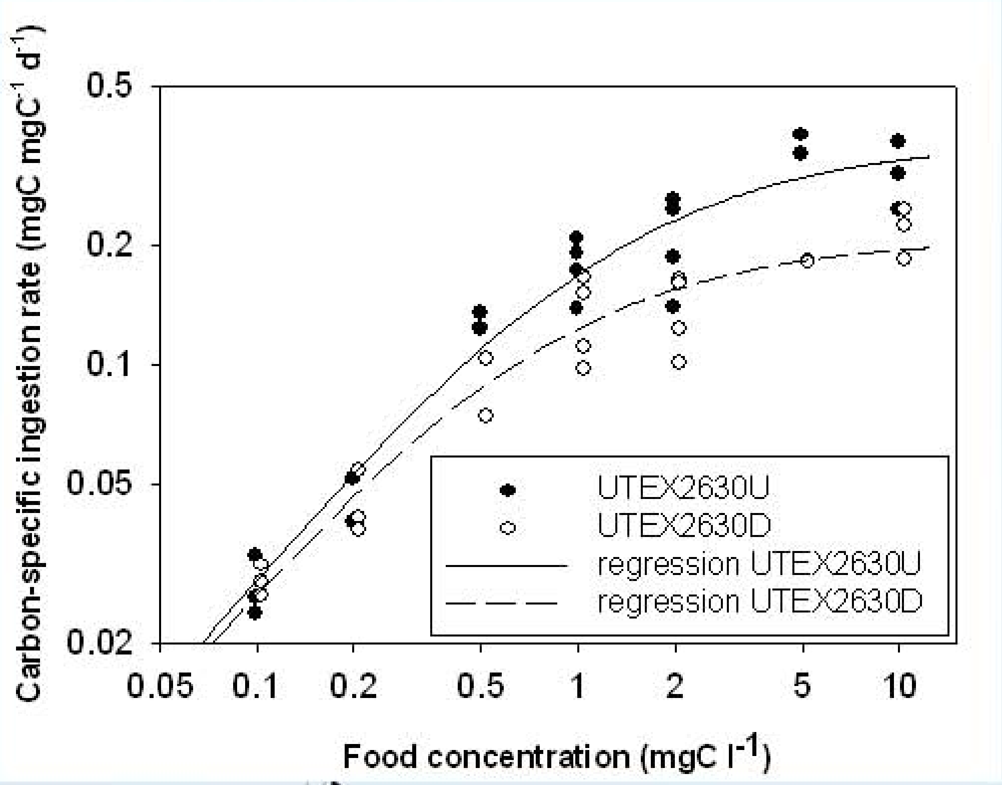
Verschoor unpublished

evolution of inducible defences

- the defence should be effective



Verschoor, Van der Stap, Helmsing, Lürling & Van Donk (2004) J. Phycol. 40: 808-814



Verschoor, Zadereev & Mooij (2007). Limnol. Oceanogr. In press [52(5)]

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Model system inducible defences

- *Scenedesmus obliquus*
  Chlorophyta, Chlorophyceae

- *Brachionus calyciflorus*
  Rotifera

- *Asplanchna brightwelli*
  Rotifera

Mathematical model

$$\frac{dP_1}{dt} = r_1 P_1\left(1 - \frac{P_1}{k} - \frac{wP_2}{k}\right) - i_1 P_1\left(1 - \frac{1}{\left(1 + \left(\frac{(H_1 + H_2)}{g_1}\right)^{b_1}\right)}\right) + \frac{i_1 P_2}{\left(1 + \left(\frac{(H_1 + H_2)}{g_1}\right)^{b_1}\right)} - \frac{v_{11}(H_1 + H_2)P_1}{1 + (v_{11}h_{11}P_1 + v_{21}h_{21}P_2)} - s_1 P_1 \qquad (2a)$$

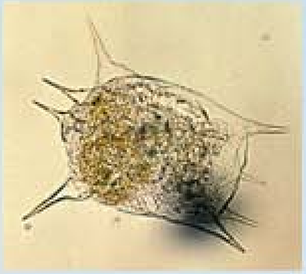
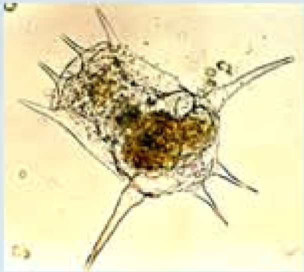
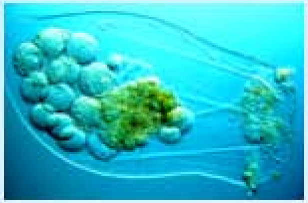
$$\frac{dP_2}{dt} = r_1 P_2\left(1 - \frac{P_2}{k} - \frac{wP_1}{k}\right) + i_1 P_1\left(1 - \frac{1}{\left(1 + \left(\frac{(H_1 + H_2)}{g_1}\right)^{b_1}\right)}\right) - \frac{i_1 P_2}{\left(1 + \left(\frac{(H_1 + H_2)}{g_1}\right)^{b_1}\right)} - \frac{v_{21}(H_1 + H_2)P_2}{1 + (v_{11}h_{11}P_1 + v_{21}h_{21}P_2)} - s_2 P_2 \qquad (2b)$$

$$\frac{dH_1}{dt} = \frac{c_1 H_1(v_{11}P_1 + v_{21}P_2)}{1 + (v_{11}h_{11}P_1 + v_{21}h_{21}P_2)} - i_2 H_1\left(1 - \frac{1}{\left(1 + \left(\frac{C}{g_2}\right)^{b_2}\right)}\right) + \frac{i_2 H_2}{\left(1 + \left(\frac{C}{g_2}\right)^{b_2}\right)} - \frac{v_{12}CH_1}{1 + (v_{12}h_{12}H_1 + v_{22}h_{22}H_2)} - s_3 H_1 \qquad (2c)$$

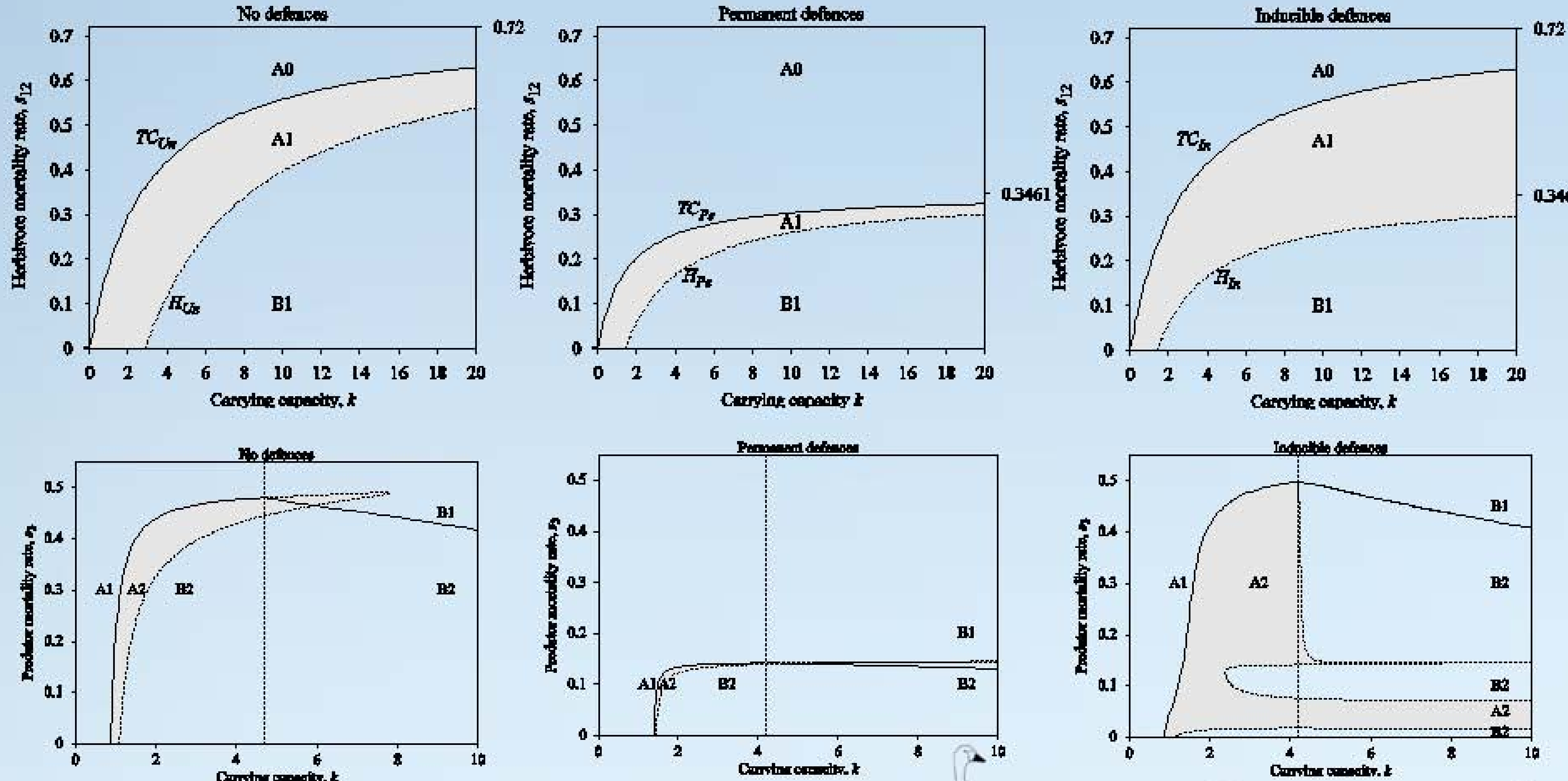
$$\frac{dH_2}{dt} = \frac{c_1 H_2(v_{11}P_1 + v_{21}P_2)}{1 + (v_{11}h_{11}P_1 + v_{21}h_{21}P_2)} + i_2 H_1\left(1 - \frac{1}{\left(1 + \left(\frac{C}{g_2}\right)^{b_2}\right)}\right) - \frac{i_2 H_2}{\left(1 + \left(\frac{C}{g_2}\right)^{b_2}\right)} - \frac{v_{22}CH_2}{1 + (v_{12}h_{12}H_1 + v_{22}h_{22}H_2)} - s_4 H_2 \qquad (2d)$$

$$\frac{dC}{dt} = \frac{c_2 C(v_{12}H_1 + v_{22}H_2)}{1 + (v_{12}h_{12}H_1 + v_{22}h_{22}H_2)} - s_5 C \qquad (2e)$$

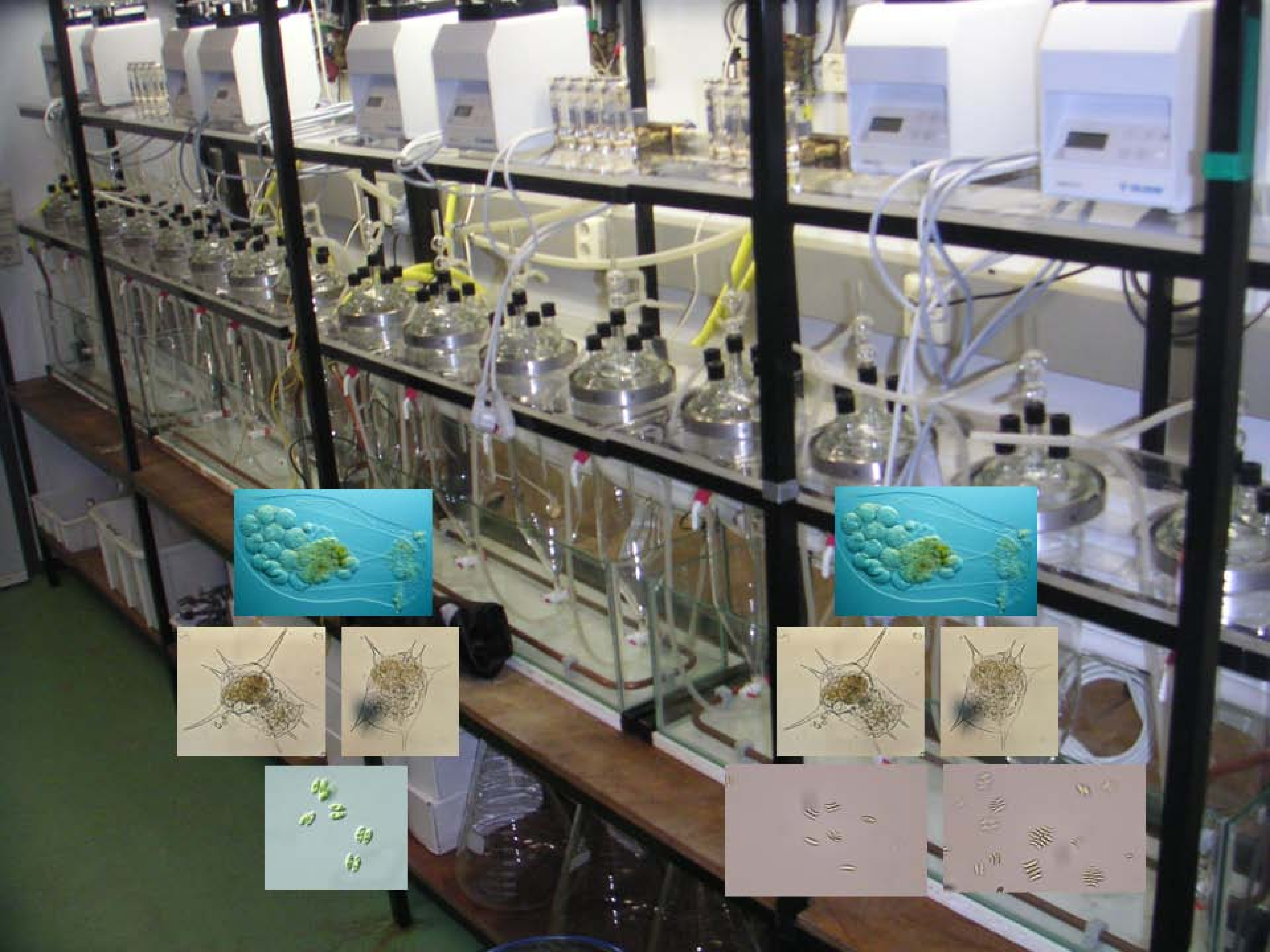


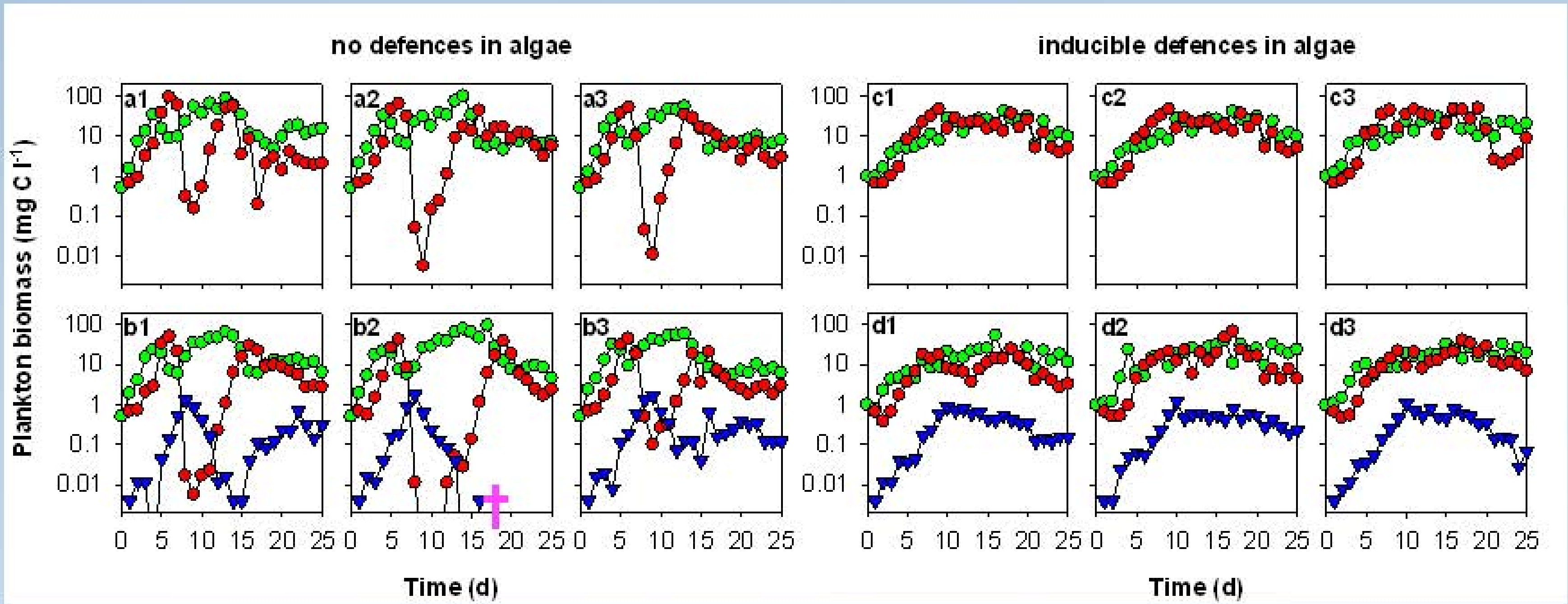




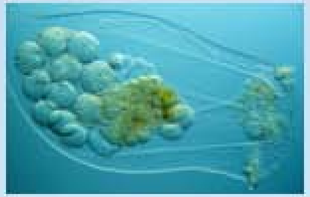
Model predictions: stability and coexistence

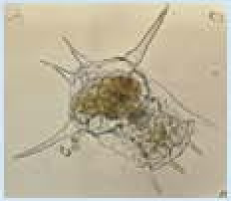


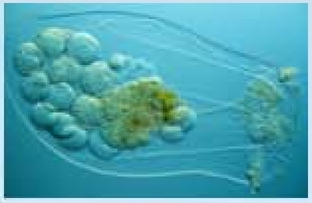
Vos, Kooi, DeAngelis, Mooij (2004). Oikos 105: 471-480.

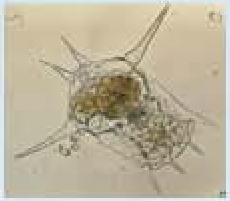












Verschoor, Vos, & Van der Stap (2004). Ecol. Lets. 7: 1143-1148

2. Abiotic interactions: ecological stoichiometry

- biochemicals have a certain chemical stoichiometry: C, H, O, N, P, S, K, Si, Fe, Mg, etc.
- this stoichiometry poses constraints on biochemical/molecular processes, and therefore also on higher levels of organisation: cells, individuals, communities, food webs, ecosystems
- Environment determines availability of these elements

Andersen, T., 1997. Pelagic nutrient cycles. Herbivores as sources and sinks. Springer-Verlag, Berlin.

Sterner, R.W., & J.J. Elser, 2002. Ecological stoichiometry: the biology of elements from molecules to biosphere. Princeton University Press, Princeton, New Jersey.

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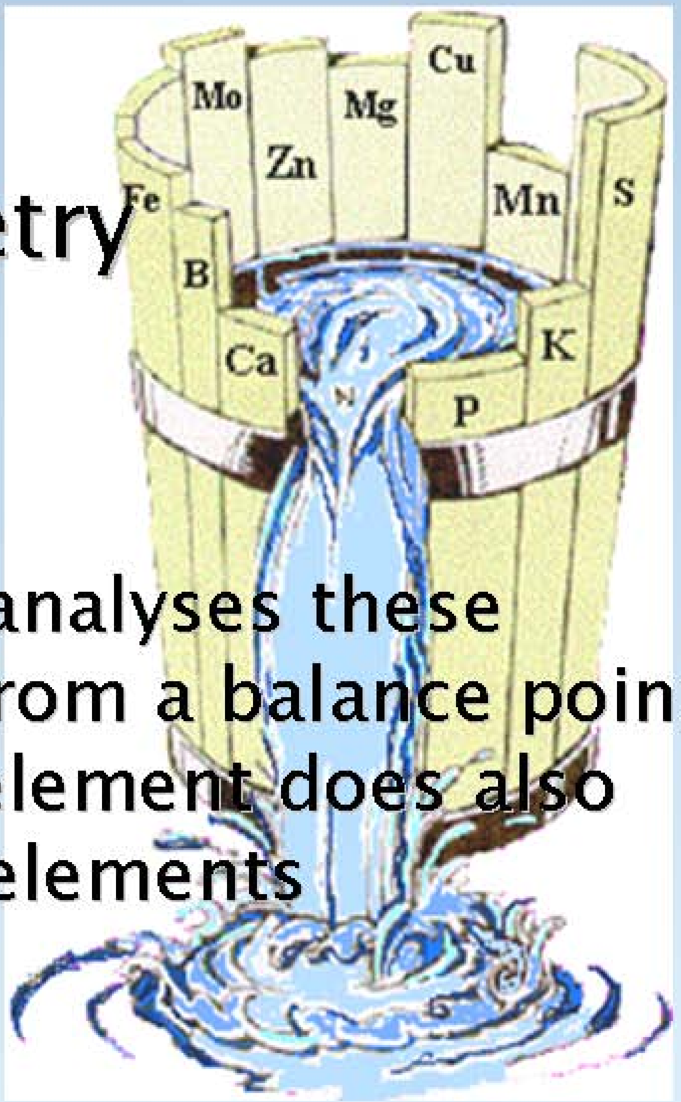
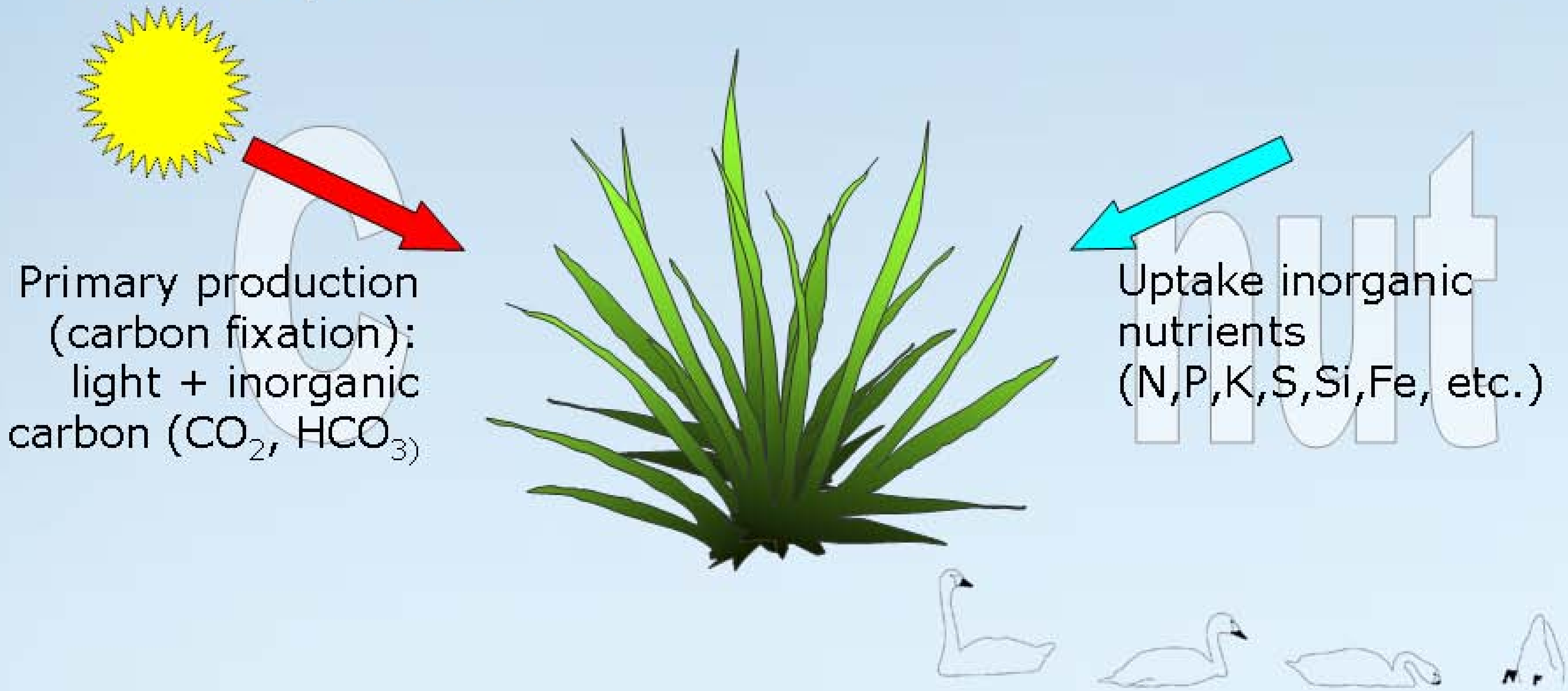
ecological stoichiometry



- ecological stoichiometry analyses these biochemical constraints from a balance point of view: too little of one element does also mean too much of other elements

primary producers

- photosynthesis and nutrient uptake are not tightly coupled: carbon fixation and nutrient uptake more or less independent



primary producers

- carbon:nutrient ratio of plant (algal) biomass varies according to abiotic conditions
  - High light, carbon and or low nutrients: high carbon:nutrient ratio
  - Low light, carbon and/or high nutrients: low carbon:nutrient ratio

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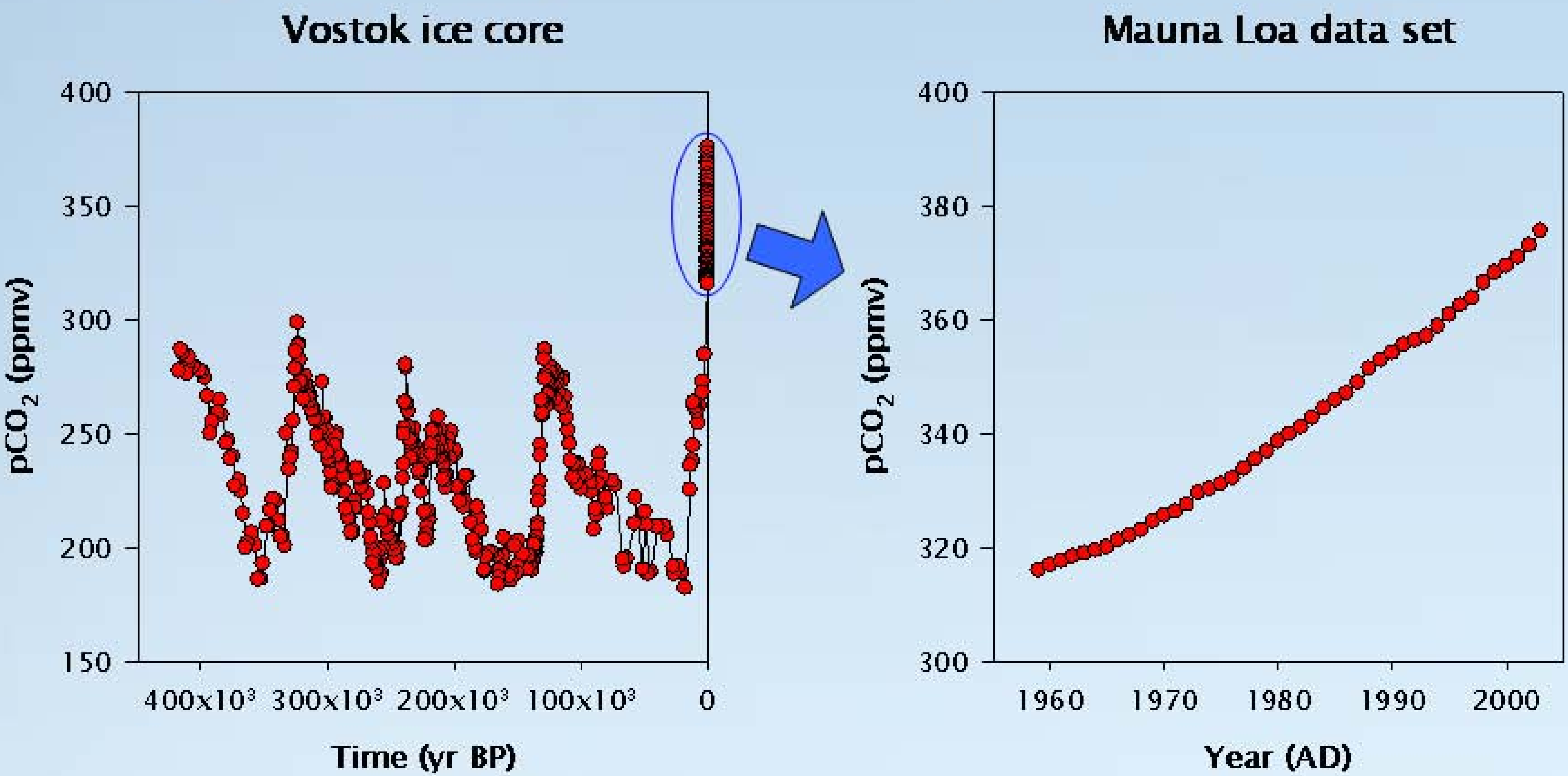
rising atmospheric CO_2 concentration



Data: J.-M. Barnola et al. (Vostok), C.D. Keeling et al. (Mauna Loa)

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hypotheses: CO_2 and phytoplankton

- Increase in primary productivity
- Increase in C:nutrient levels phytoplankton biomass

Test in mesoscale laboratory enclosures (Limnotrons)

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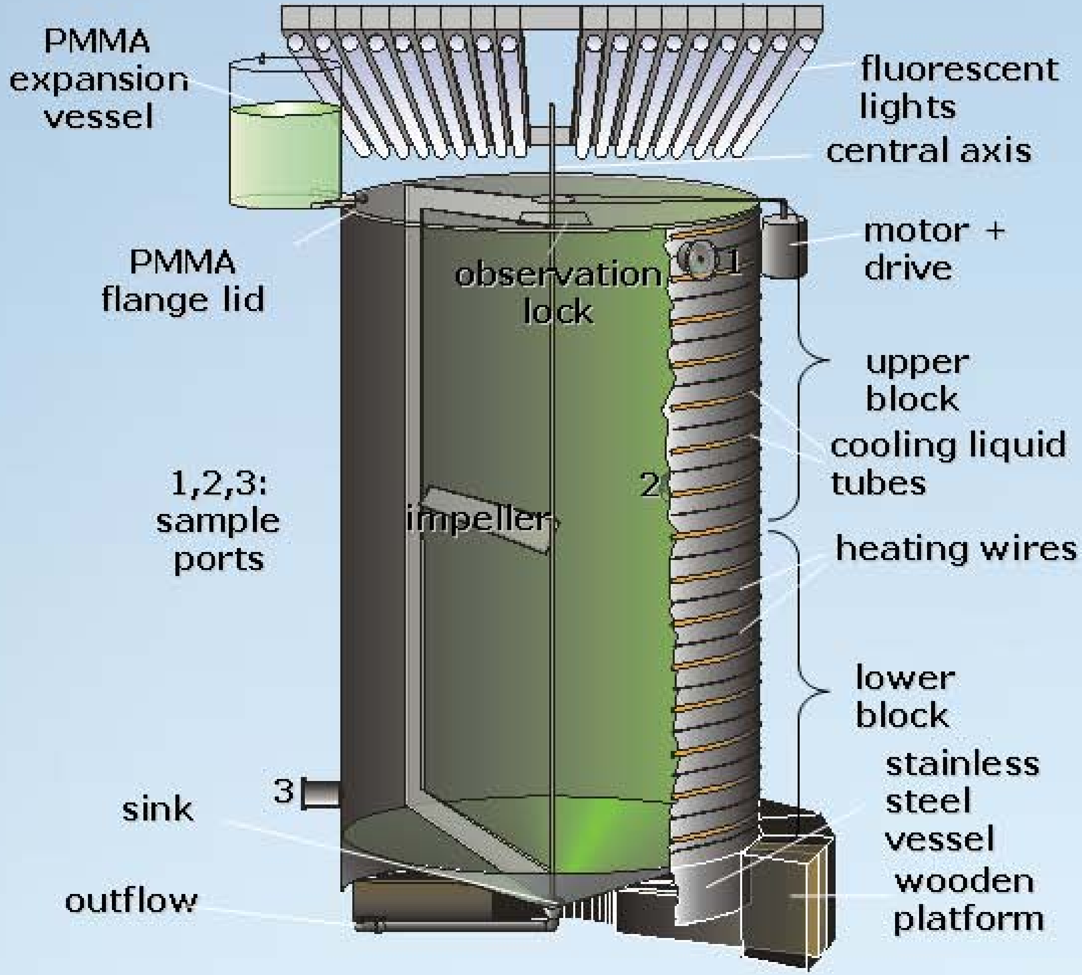
The Limnotrons



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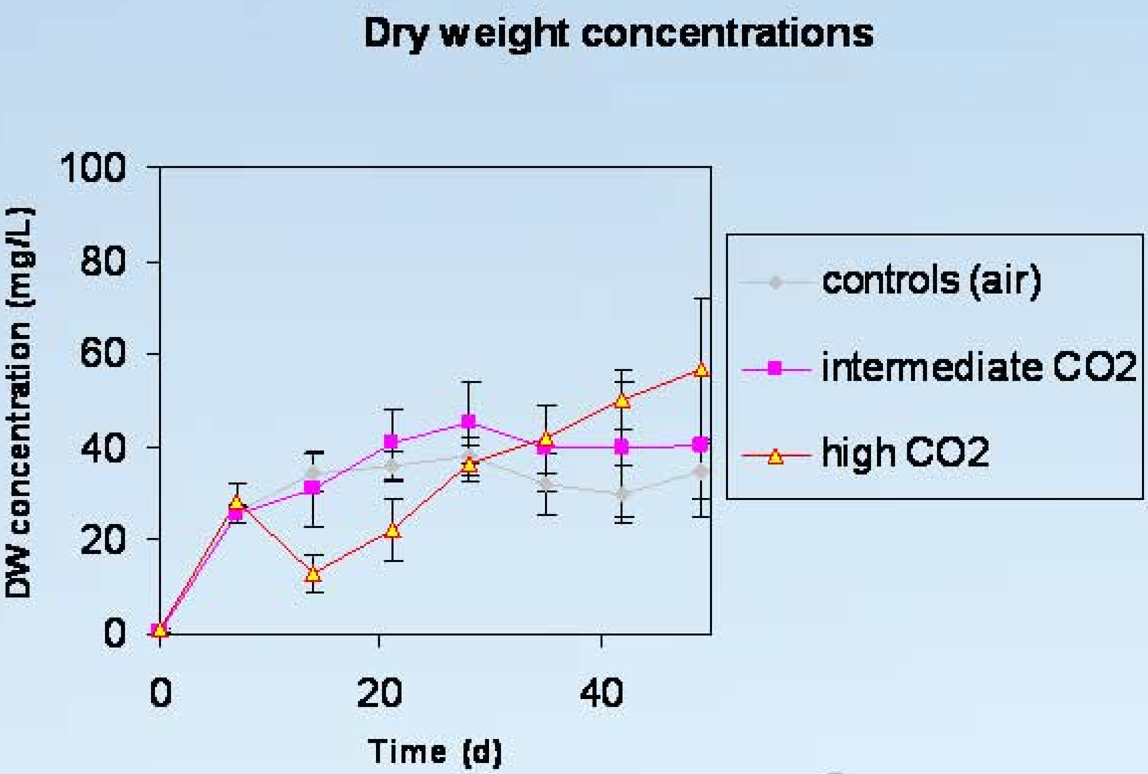
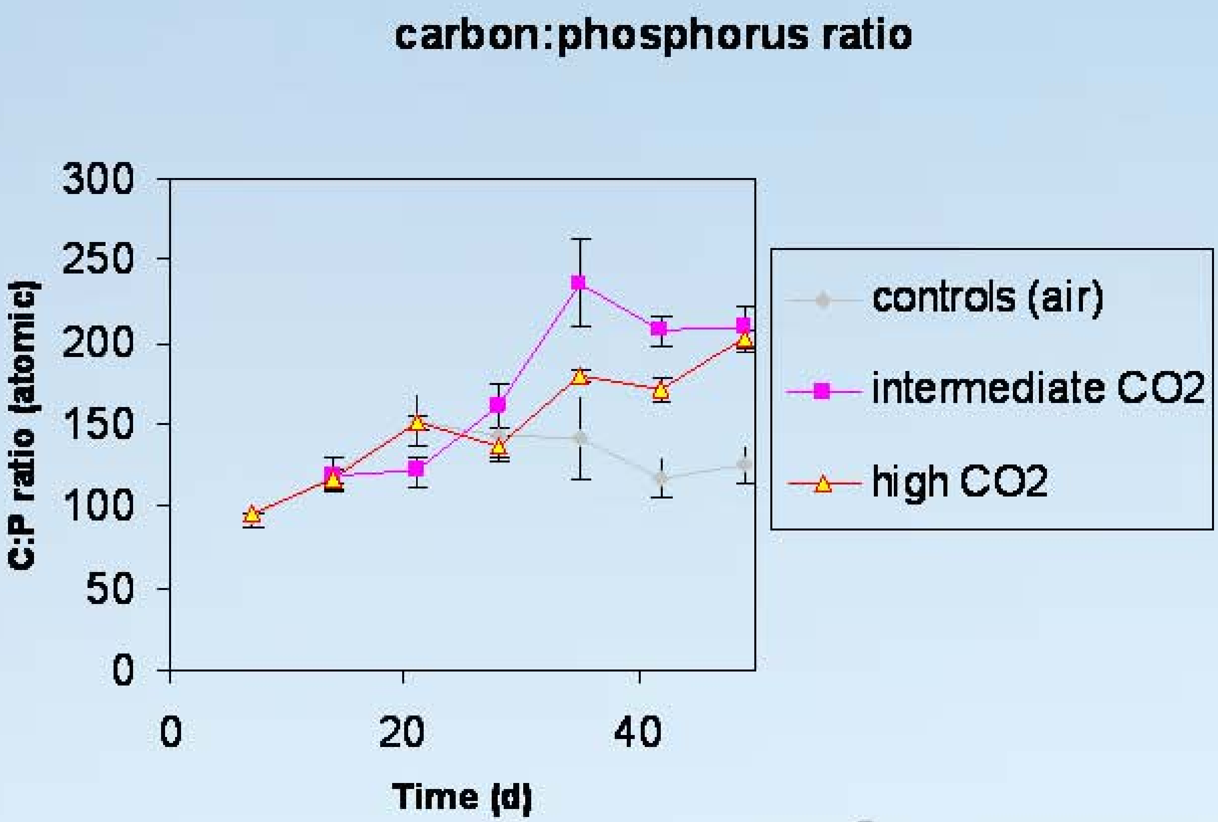
phytoplankton biomass



chemical composition



Zooplankton/higher trophic levels

- Less flexible stoichiometry (stricter homeostasis), but higher nutrient demand
- Food can only be taken up as discrete particles: unable to profit from increased productivity due to high carbon = low nutrients

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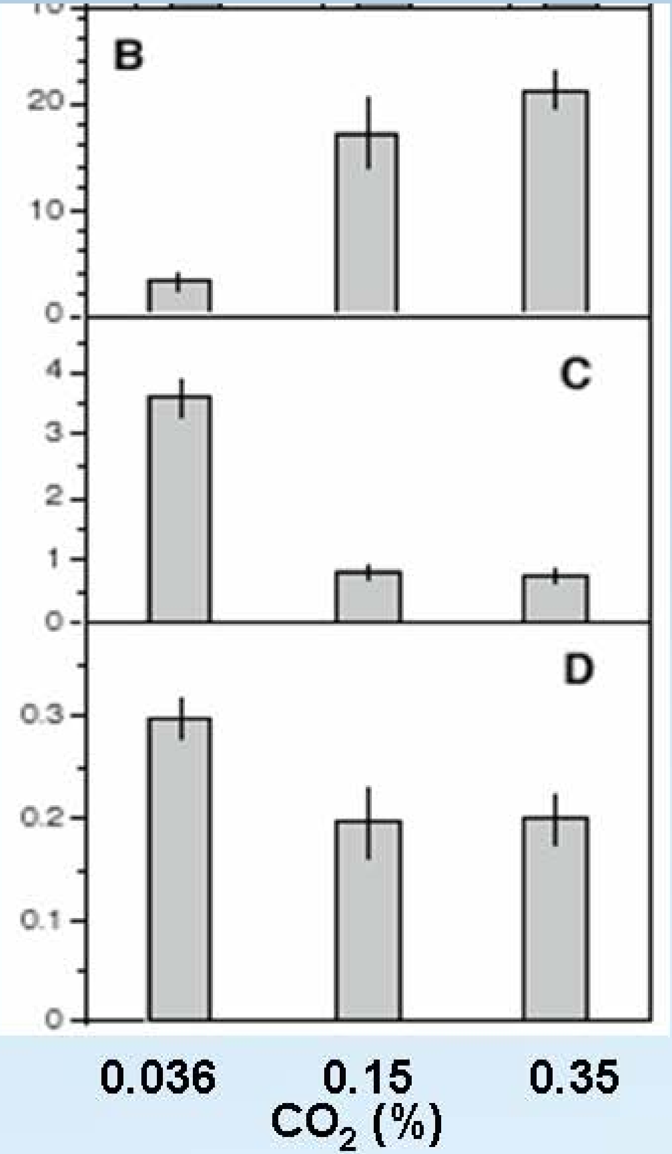
- Algal biomass

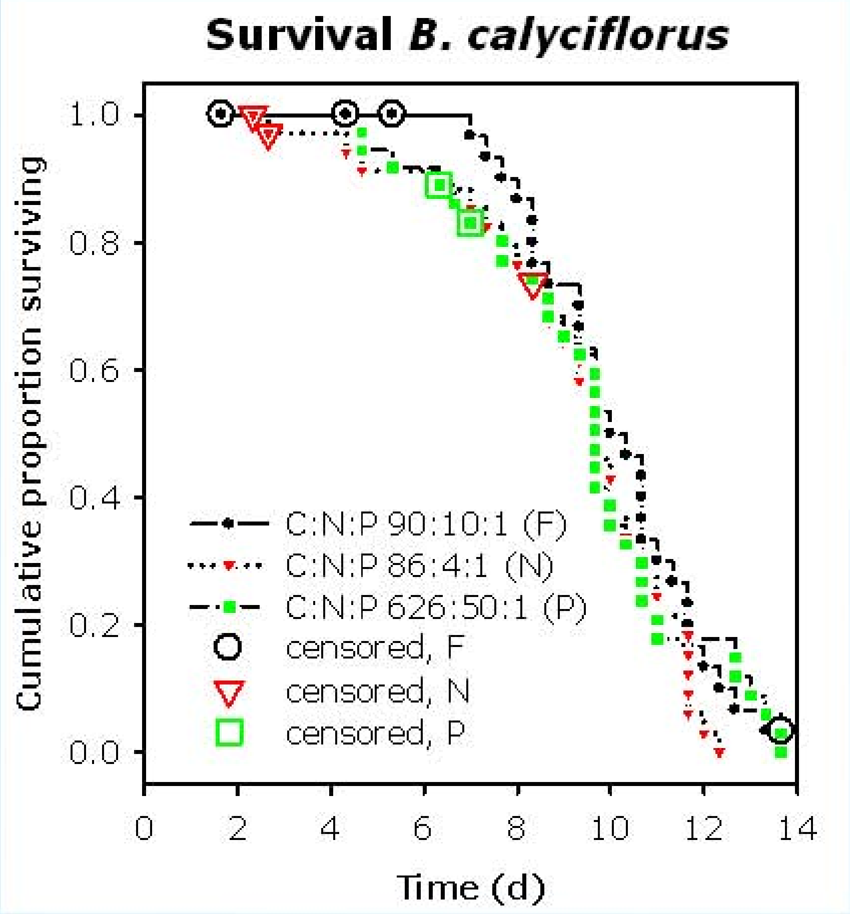
- Algal P:C ratio

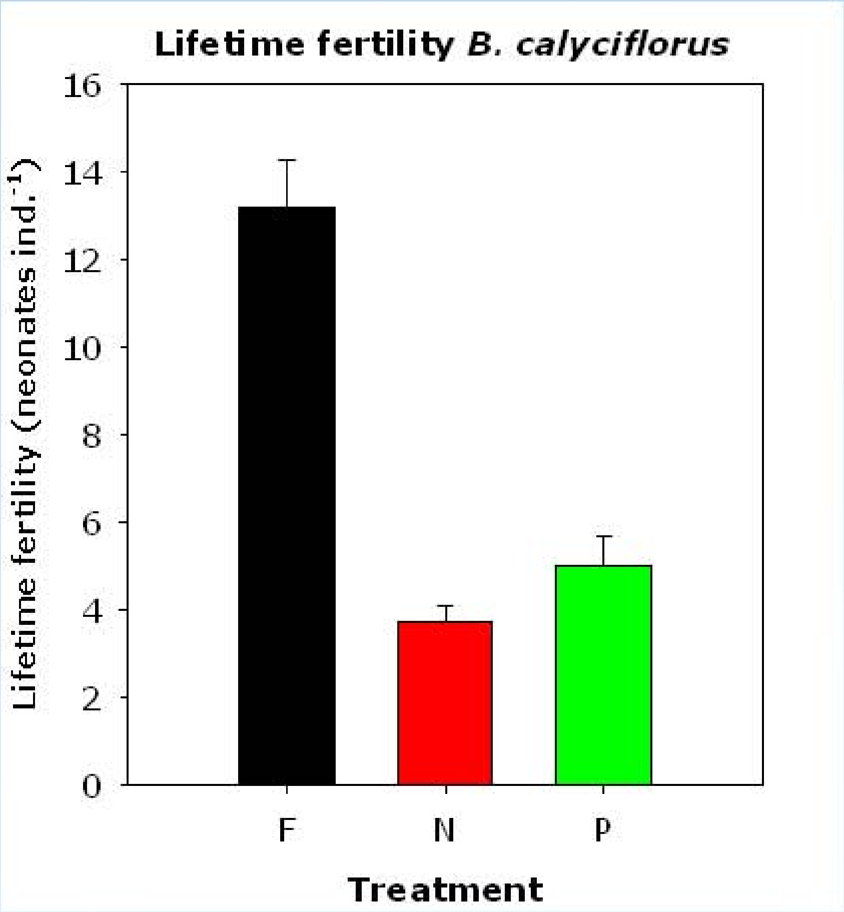
- *Daphnia* growth rate



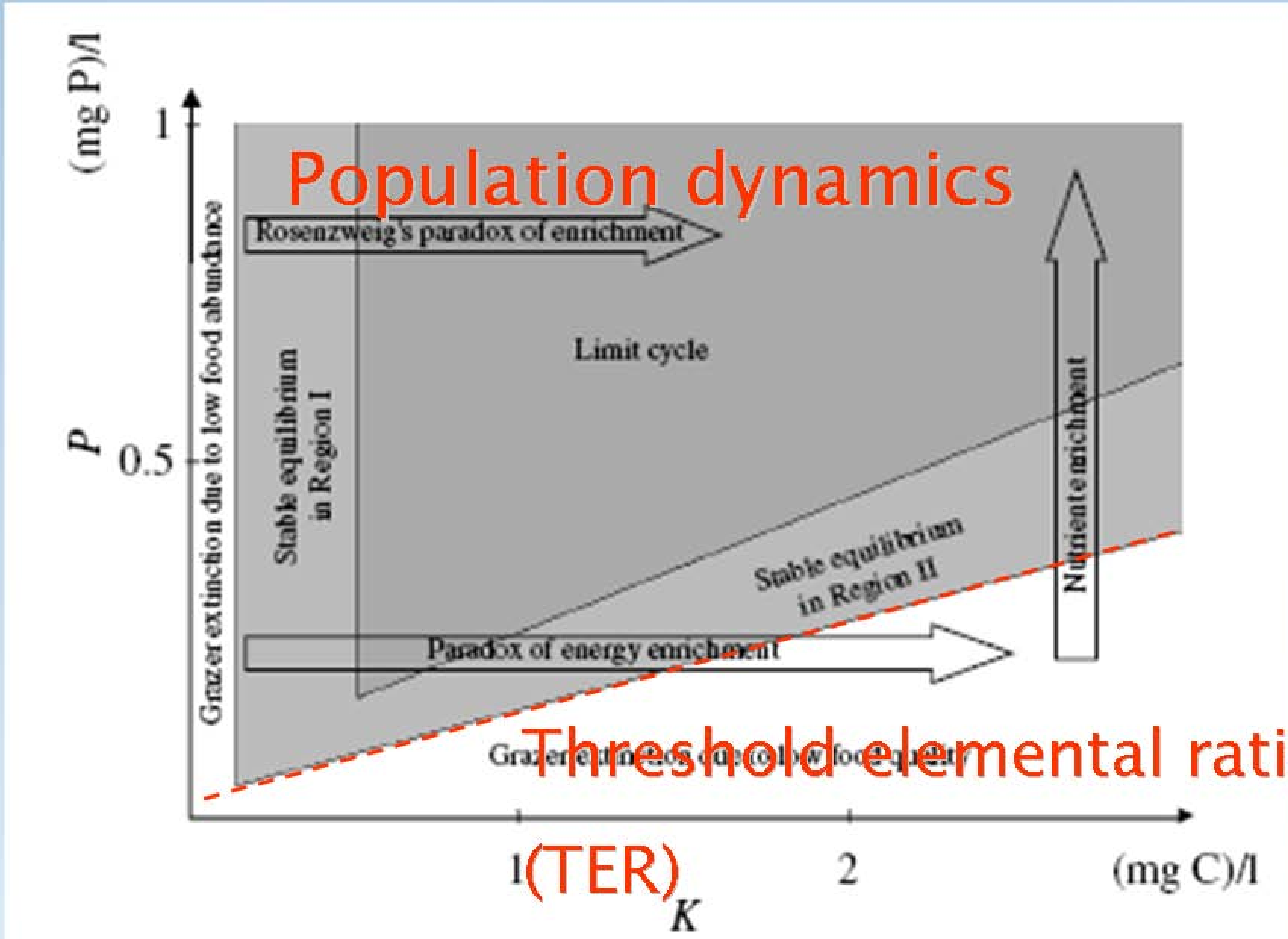
Urabe, Togari & Elser (2003) Global Change Biol. 9: 818–825.

Adult survival unaffected at moderate changes in stoichiometry, unlimited feeding





Jensen & Verschoor (2004). Freshw. Biol. 49: 1138-1151



Loladze, Kuang & Elser, 2000. Bull. Math. Biol. 62: 1137–1162

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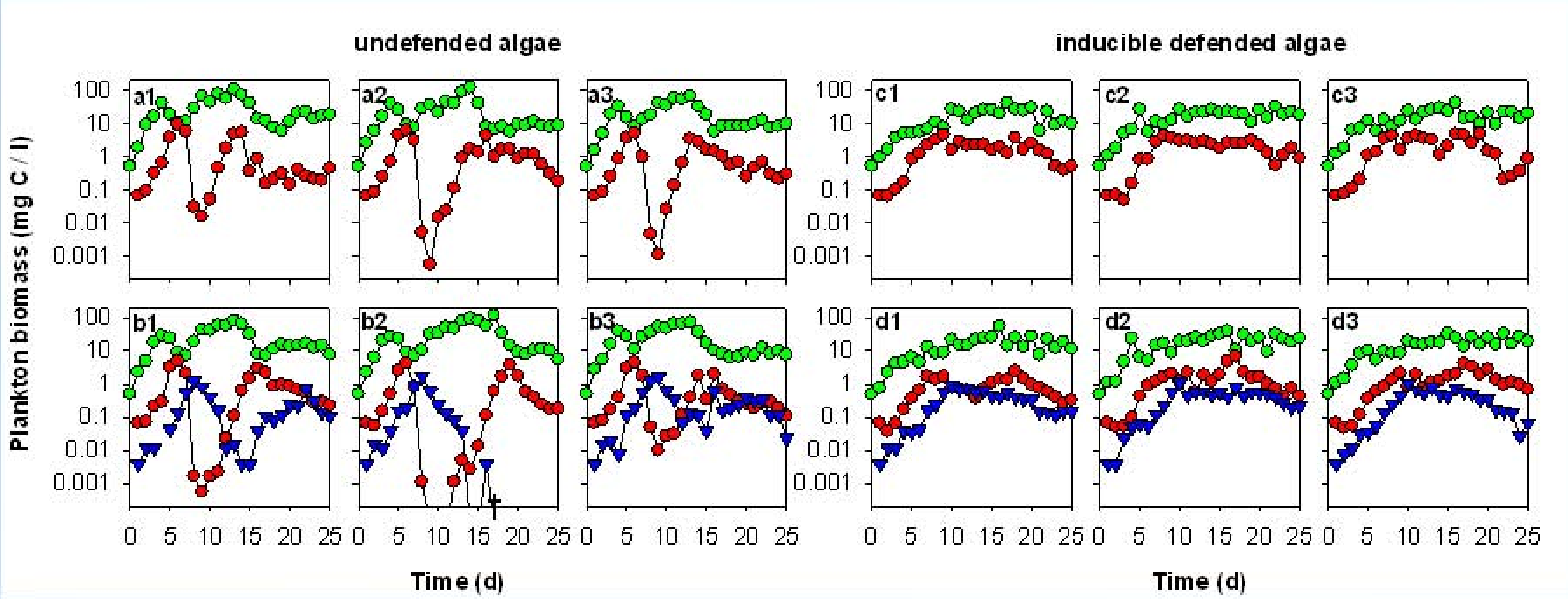
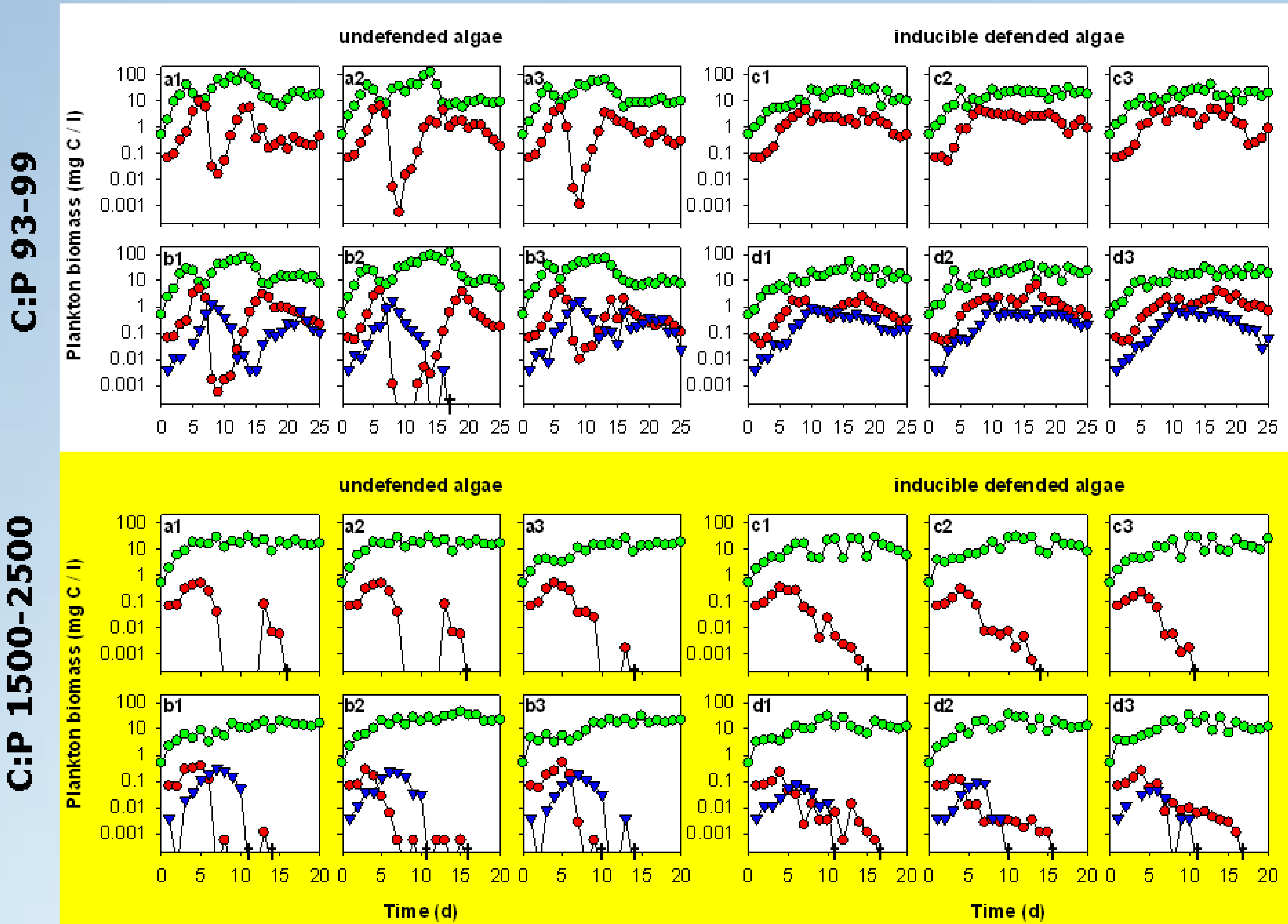
Stoichiometry and effects on higher trophic levels





Verschoor, Vos & Van der Stap (2004). Ecol. Lets. 7: 1143-1148

conclusions

- Inducible defences stabilize population fluctuations and hence prevent *stochastic* extinctions
- Stoichiometric unbalanced food quality (far from Redfield) may also stabilize but cause *deterministic* extinctions beyond threshold elemental ratio

Thank you!