Modeling the copepod-phytoplankton interactions in presence of chemical defenses

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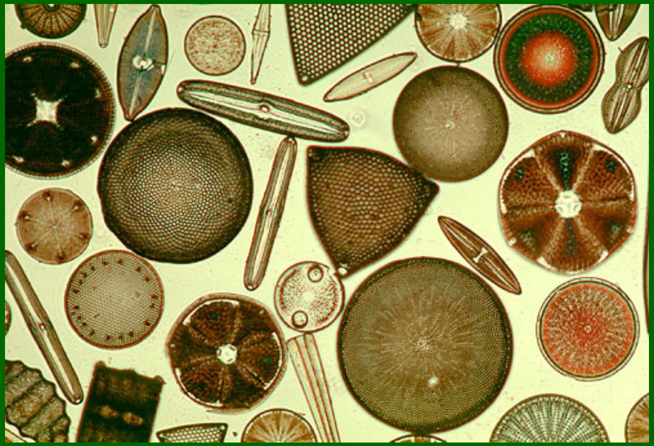
background

chemical defenses

phytoplankton

background



diatoms

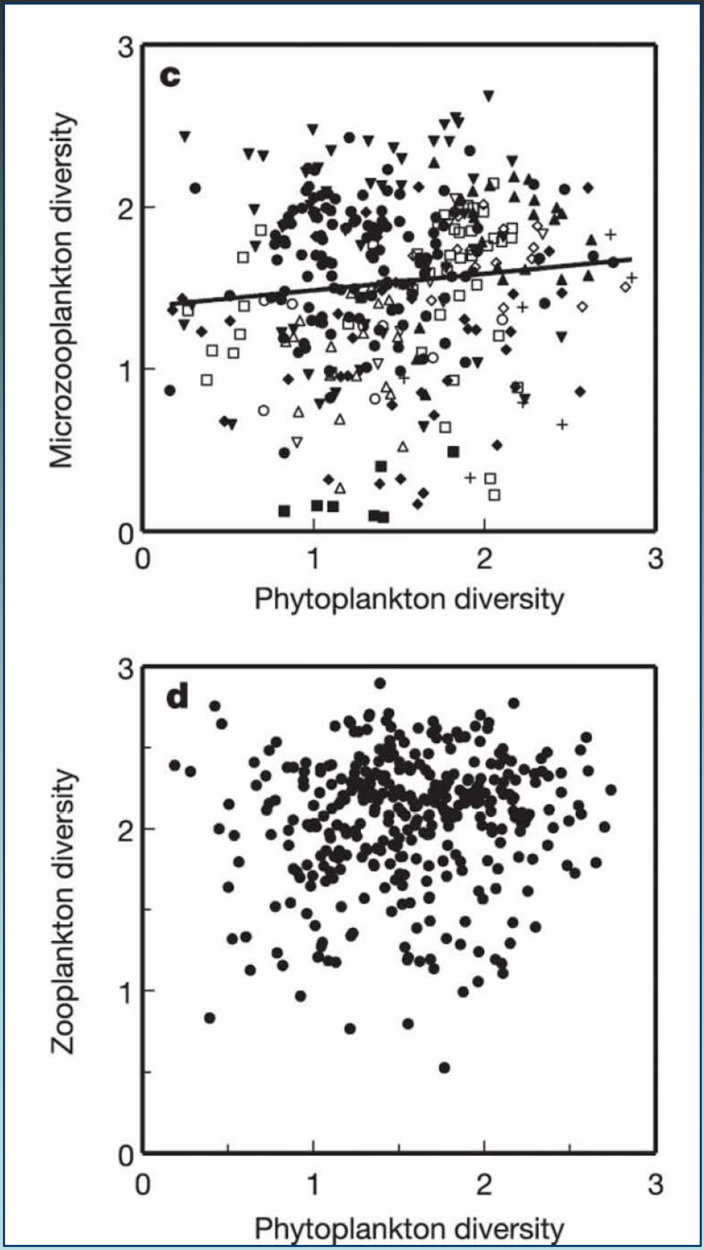
the problem

Hampering grazers would benefit
not only the chemically-defended clone
but also other phytoplankton species
if grazing is not selective

IMPLICATIONS

ecological | **evolutionary**

is grazing selective?



Large-scale observations hint at non-selectivity

Irigoien *et al.*, 2004

the question

To what extent insidious chemical defense may give (selective) advantage to clones producing it?

the approach

An object-oriented IBM was implemented to analyze the patterns emerging from the grazing of a copepod species on two different phytoplankton species (one with chemical defense).

Different possible scenarios (traits) were tested

Preliminary results are presented

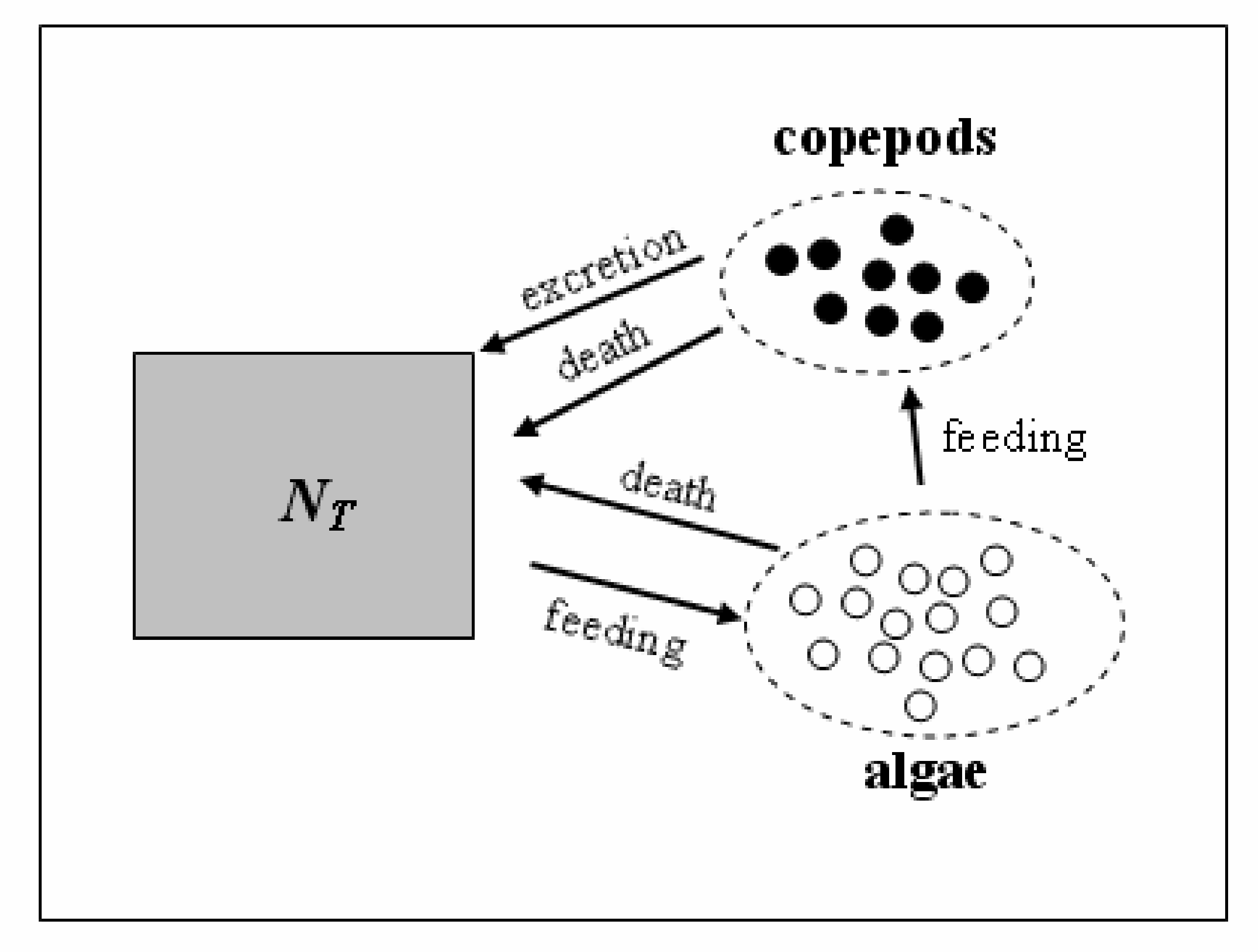
the object-oriented approach

Each virtual individual is a separate entity containing its own traits and data.

The information is stored and processed in each object, instead than in the overall structure.

Object-oriented programming is particularly suited for IBMs

the model scheme



- **the system is closed**
- **the trophic link is represented by N transfer**

N phytoplankton content

$$N_{j+1} - N_j = V_{\max} \frac{N_j}{N_j + K} \Delta t + g_j$$

Assumptions:

- ✓ both phytoplankton species have the same N content
- ✓ cells divide when N doubles
- ✓ at each step, the random component is the same for all cells

Copepod feeding

$$w_i = V_{\max}^{i,s} \frac{m_i}{m_i + K^{i,s}} \Delta t + g_s^i$$

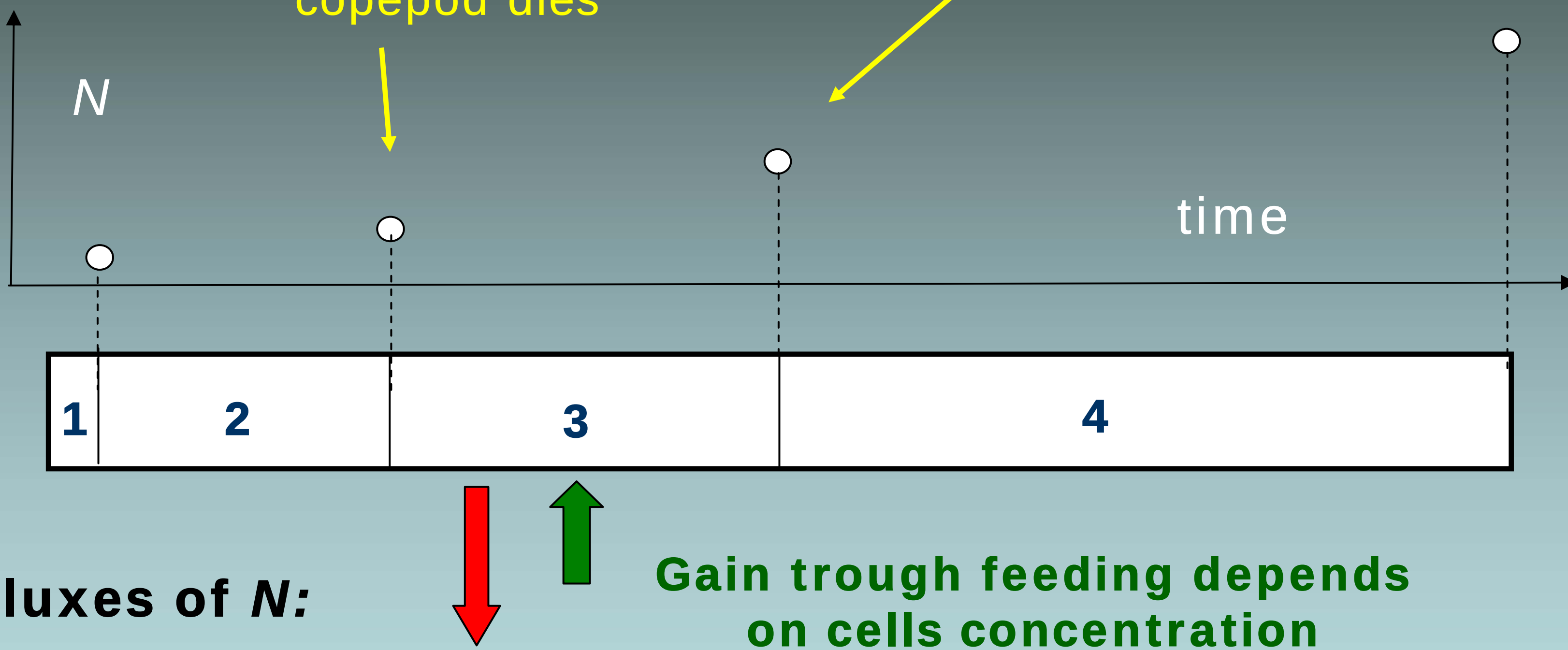
Assumptions:

- ✓ V_{max} (cells ingested / time) is used for selectivity
- ✓ the random component is individual
- ✓ a basic metabolic cost is included (resp., swimming, etc.)
- ✓ growth is both N and stage dependent

stage structure

if the *N* content goes below this value, the copepod dies

the copepod can progress to the successive stage only if its *N* content reaches this value within the max stage duration



Fluxes of *N*:

Gain trough feeding depends on cells concentration

Loss due energy consumption

copepod reproduction and mortality

Each female releases a fixed (mean ± random) number of eggs

Mortality for causes other than starvation is modelled using a survival probability, given as a function of the mortality rate μ by:

$$p = \exp(-\mu \cdot \Delta t)$$

Mortality rate depends also on diet as:

$$\mu = \frac{\sum_{i=1}^{m} w_i \mu_{i,s}}{\sum_{i=1}^{m} w_i} + \mu_{ext,s}$$

Mortality of stage 1 depends on mother's diet

initial conditions

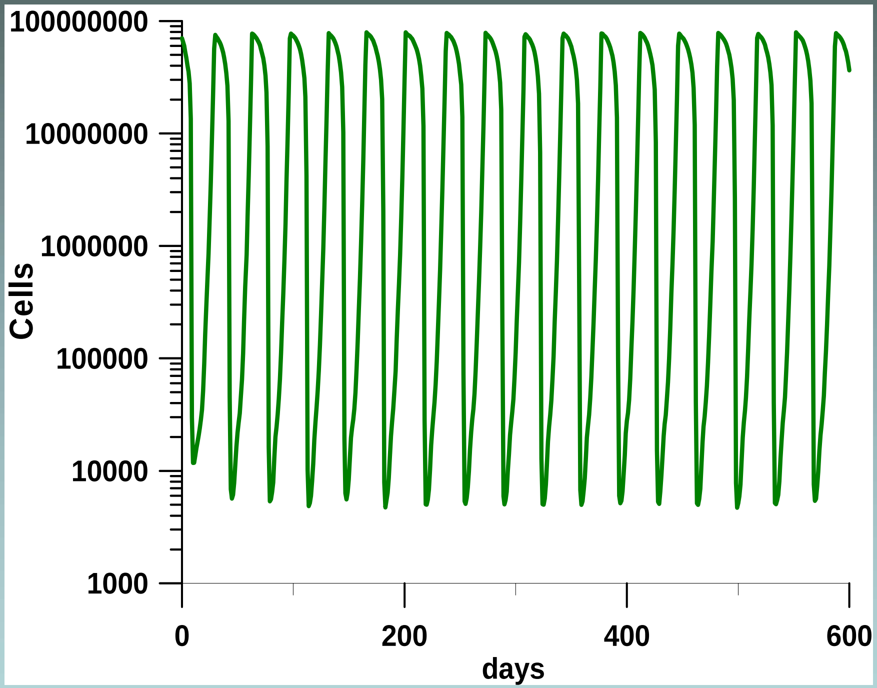
The domain corresponds to a volume of ~ 1 m^3

phytoplankton abundance	$7 \cdot 10^4$ cells·dm^{-3}
copepod abundance	1000 ind·m^{-3}
dissolved N concentration	≈0
phytoplankton max growth rate	0.92 d^{-1}
average egg production	40 eggs·female^{-1}·d^{-1}

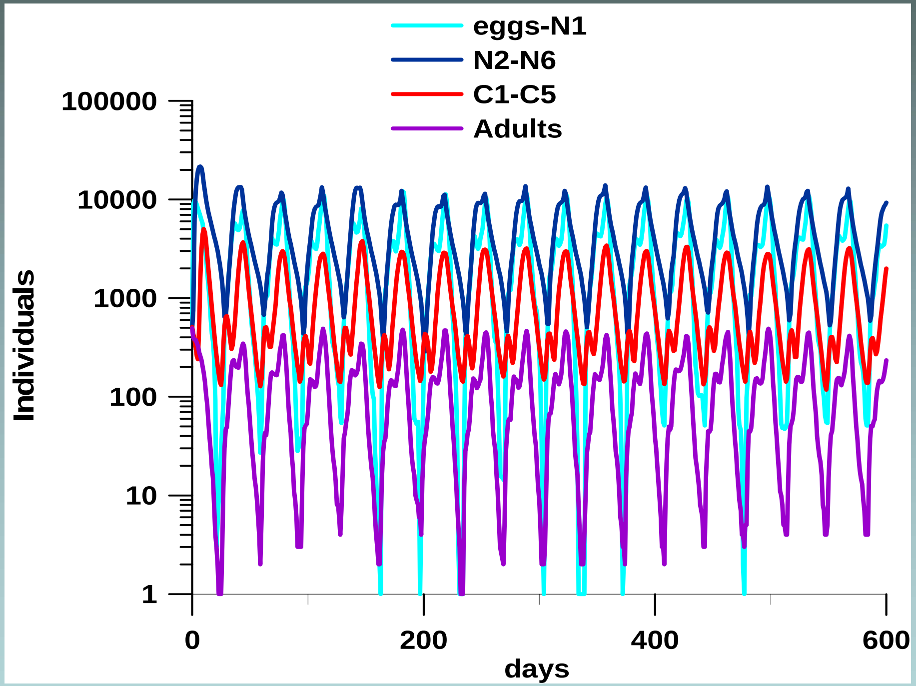
	egg-N1	N2-N6	C1-C5	Adults
Nitrogen (nmol·ind^{-1})	0.3	0.3 - 6	6 - 60	60 - 120
duration (days)	2	5	6	20
specific metabolic consumption	0.7	0.7	0.7	0.7
external mortality	0.2	0.2	0.2	0.2
max feed. rate (cells·ind^{-1}·d^{-1})		900	9000	40000

steady dynamics with *safe* nutrition

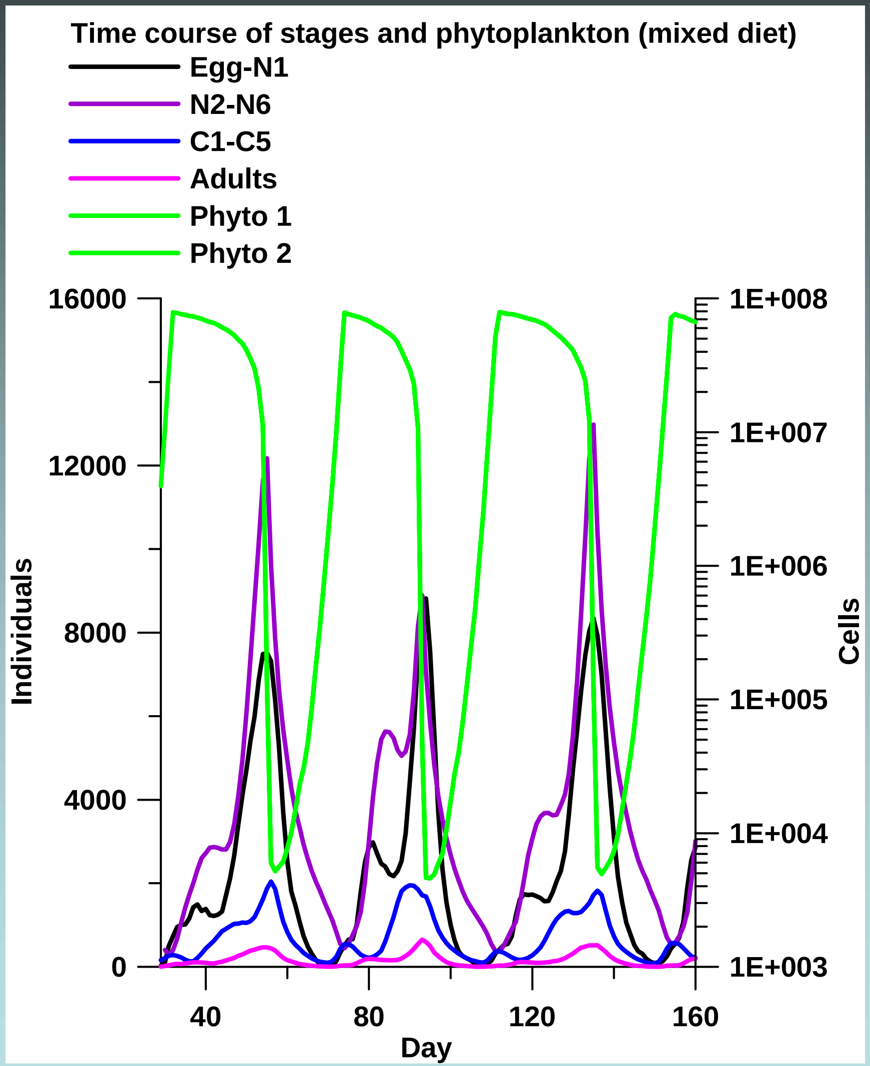
time course of phytoplankton abundance

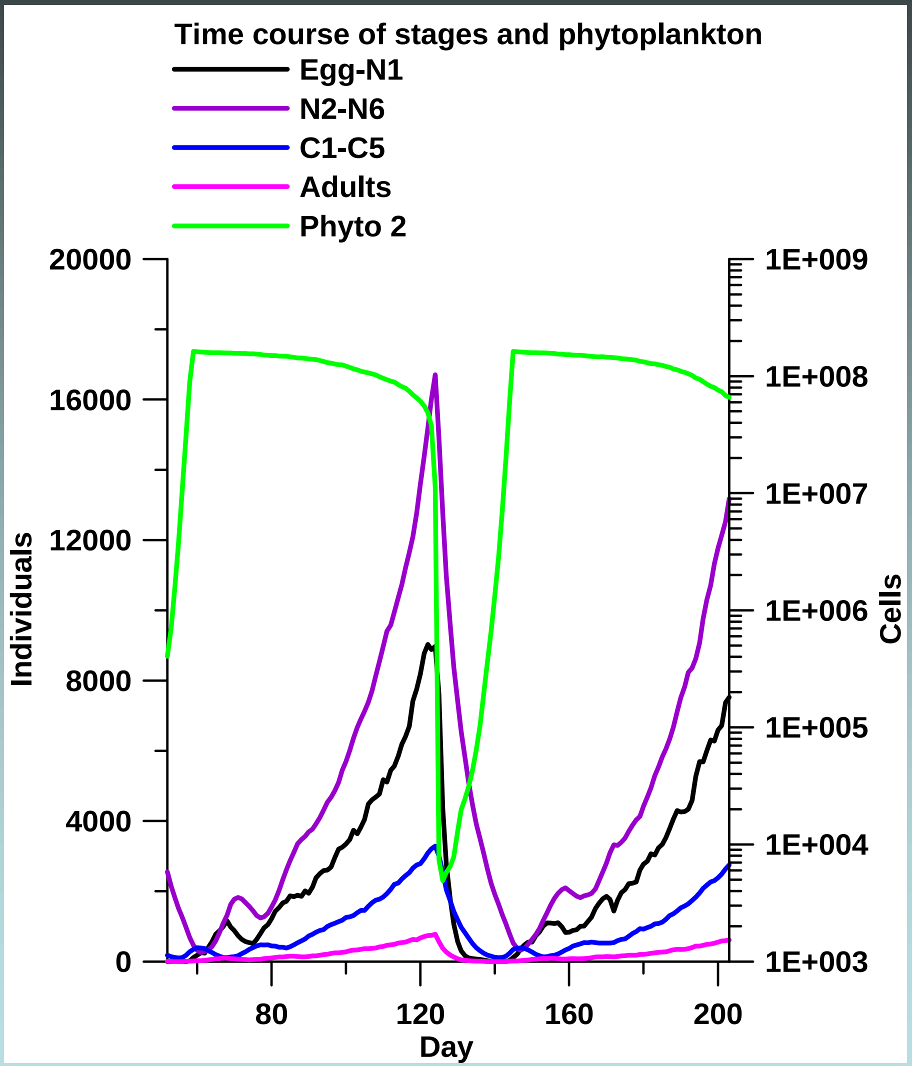


time course of copepod abundance

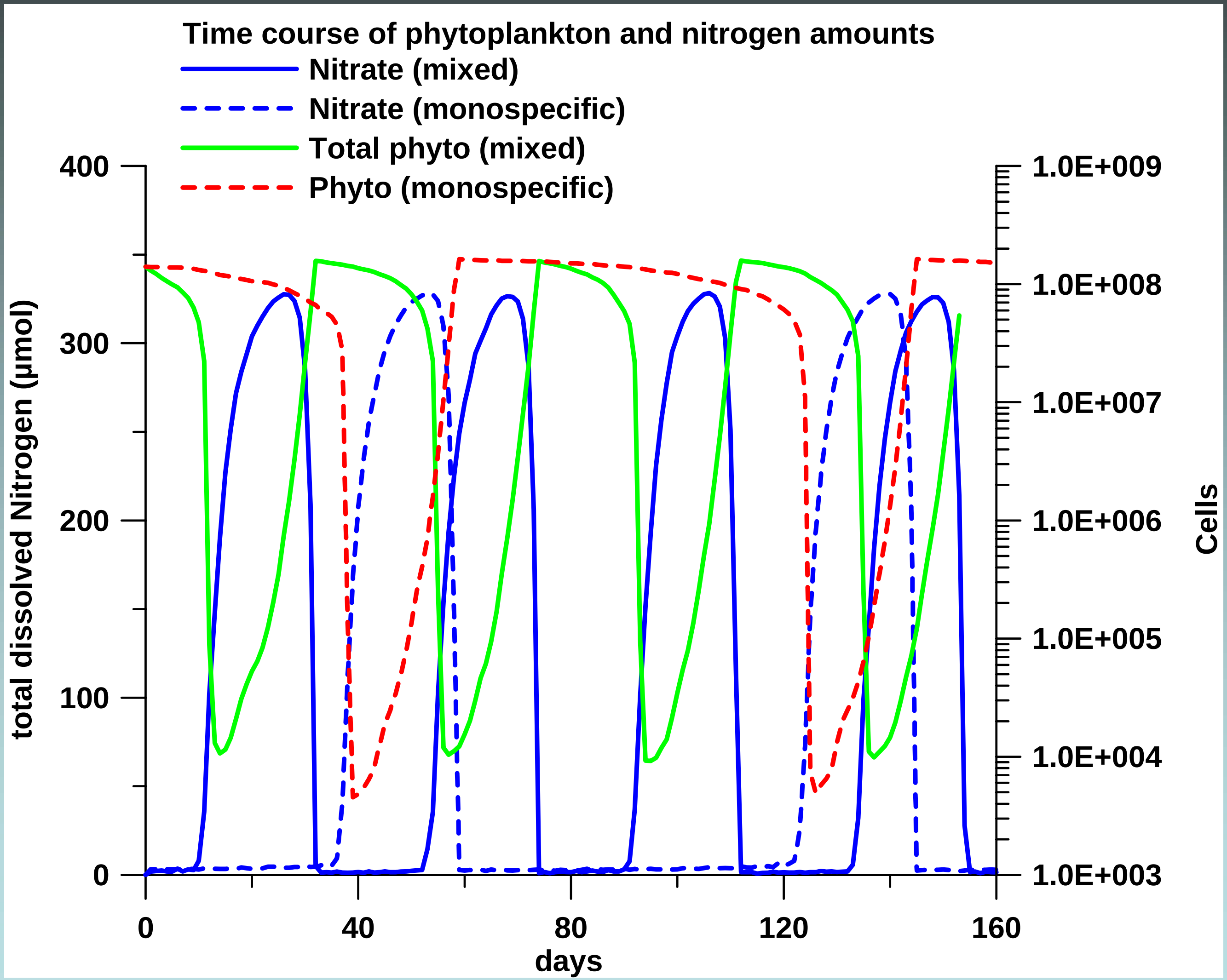


mixed vs. harmful monospecific

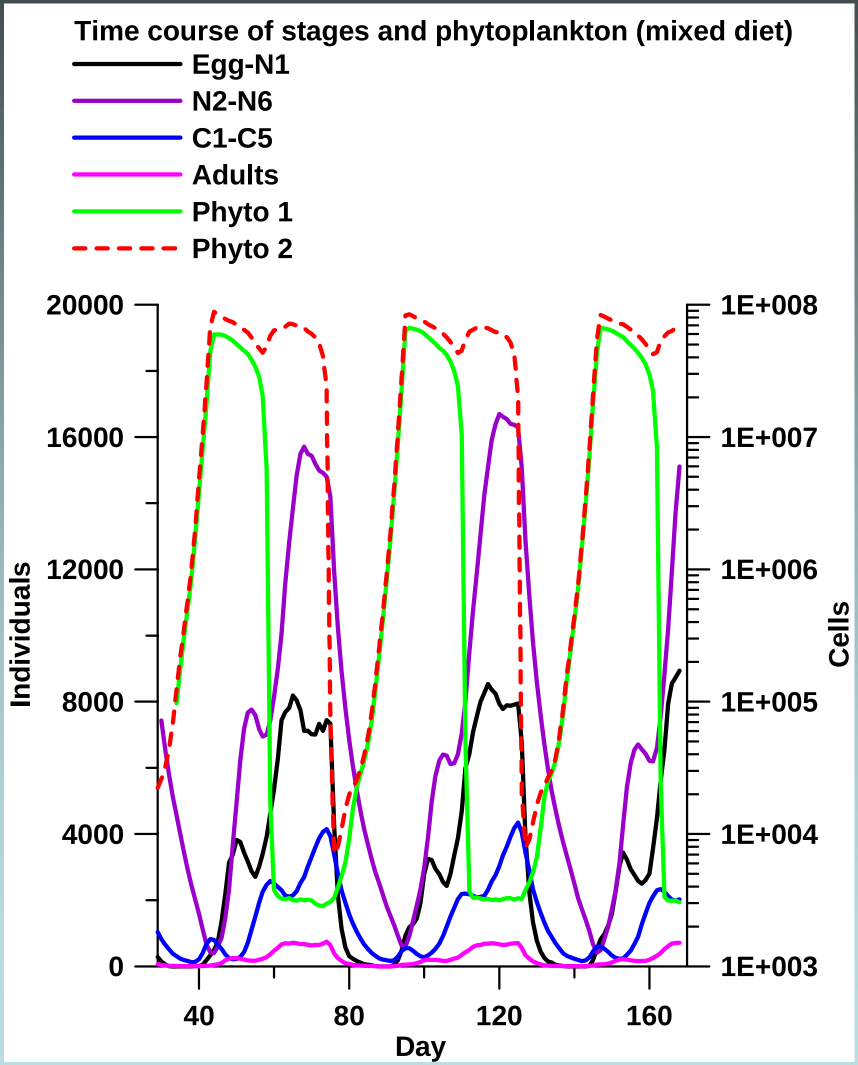




phyto-nutrients dynamics



selectivity



summary

Mean values (600 days)

	N	Phyto 1	Phyto 2	Copepods
mixed no toxicity	142.1	2.8E+07	2.8E+07	7869
mixed with toxicity	131.2	3.1E+07	3.1E+07	7071
monospecific	69.9		9.7E+07	9041
mixed with selectivity	111.8	1.6E+07	3.8E+07	12933

Concluding (ecological) remarks

Production of insidious substances does not determine dominance of phytoplankton species unless coupled with selective grazing.

Decreasing recruitment of early copepod stages increases the duration of phytoplankton bloom (but this may also depend on different causes).

A slow build-up of copepod population favors a more efficient use of resources (for what communities concerns).

Concluding (evolutionary) remark

In our simple reconstruction
the production of insidious chemicals does
increase the fitness of phytoplankton
but
more complex scenarios have to be analyzed to
test whether
those substances were selected for chemical
defense