Important traits for phytoplankton species coexistence along a disturbance gradient

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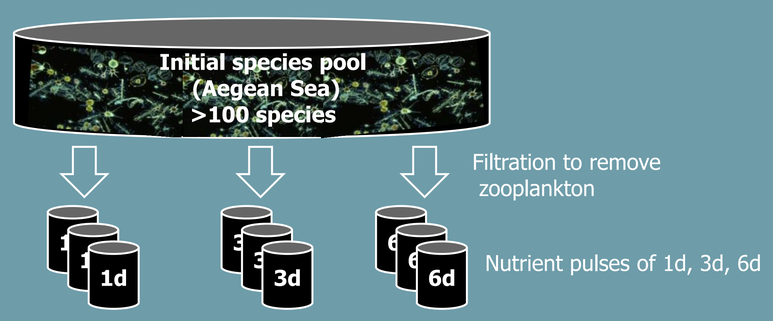
Phytoplankton species coexistence can be attributed to trade-offs between their traits as well as disturbances.
Comparing the outcome of experiments with natural phytoplankton assemblages and numerical modeling can lead to the identification of important species life history traits and their relationship that influence survival and coexistence.

Experiment

Water from the Aegean sea, containing a natural phytoplankton assemblage ,was collected and self-organized under different nutrient pulsing frequencies (disturbances) until steady-state



Model

Life history traits

Phytoplankton species
100 species

$$\frac{dN_i}{dt} = N_i\left(\min\left(\frac{\mu_{max_i}}{K_1 + R_1} \times R_1, \frac{\mu_{max_i}}{K_2 + R_2} \times R_2\right) - m_i\right) \quad i = 1-100$$

Resources
2 resources

$$\frac{dR_i}{dt} = D(S_j - R_j) - \sum_{i=1}^{n} c_{ji} \times \min\left(\frac{\mu_{max_i}}{K_{1i} + R_1} \times R_1, \frac{\mu_{max_i}}{K_{2i} + R_2} \times R_2\right) N_i \quad j = 1,2$$

Resources considered are nitrogen and phosphorus. Their concentrations were set as identical to the f/2 concentrations in the experimental pulses. The populations of 100 species self-organized under the three nutrient pulsing frequencies applied in the experiment (1d, 3d, 6d). The self-organization process lasted 3000 simulated days and produced 100 replicated assemblages. Mortality rate was set equal to dilution rate ($D=0.1d^{-1}$).

We implemented a trade-off between R^*_P and R^*_N

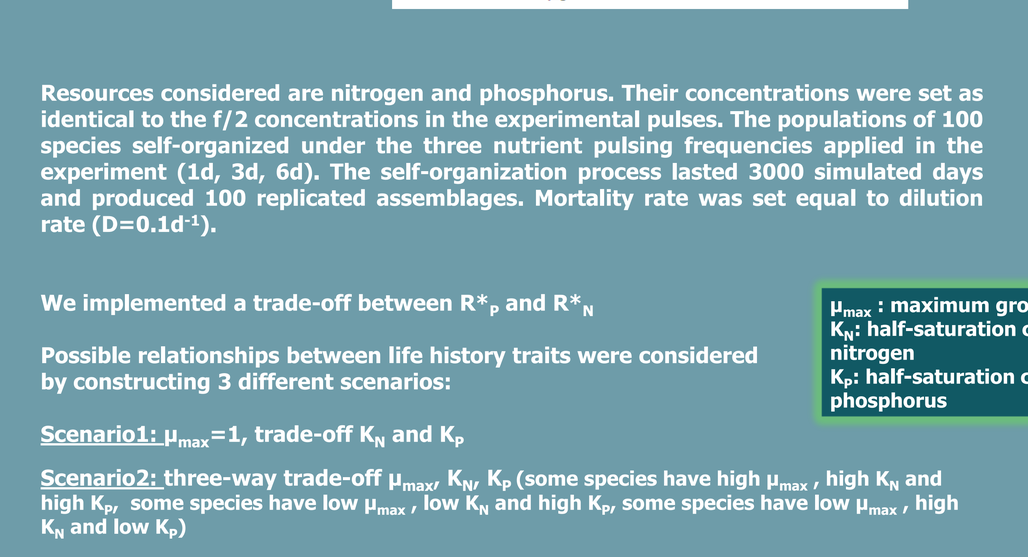
μ_{max} : maximum growth rate
K_N: half-saturation constant for nitrogen
K_P: half-saturation constant for phosphorus

Possible relationships between life history traits were considered by constructing 3 different scenarios:

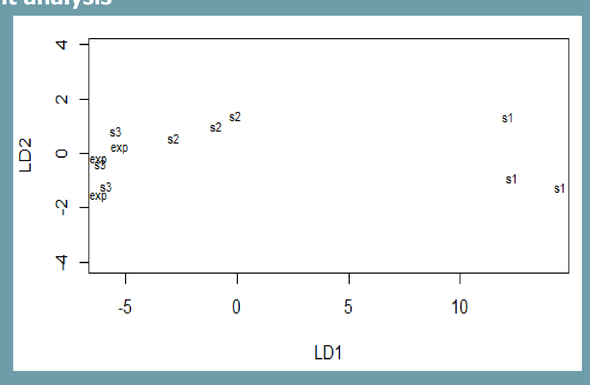
Scenario1: μ_{max}=1, trade-off K_N and K_P

Scenario2: three-way trade-off μ_{max}, K_N, K_P (some species have high μ_{max} , high K_N and high K_P, some species have low μ_{max} , low K_N and high K_P, some species have low μ_{max} , high K_N and low K_P)

Scenario3: superior competitor for two traits (some species have low μ_{max} , low K_N and low K_P, some species have high μ_{max} , low K_N and high K_P, some species have high μ_{max} , high K_N and low K_P)

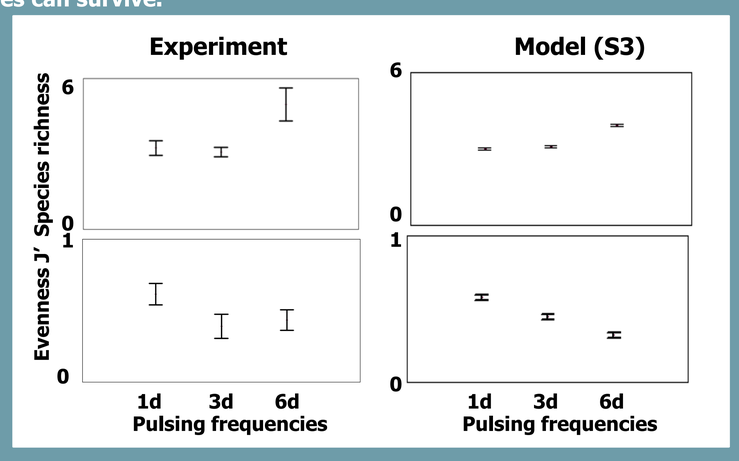


Scenario 3 (S3) best describes experimental observations (exp) when considering assemblage structure characteristics, as evidenced by discriminant analysis



Assemblage structure: **Low frequency pulses present higher richness**
High frequency pulses present higher evenness

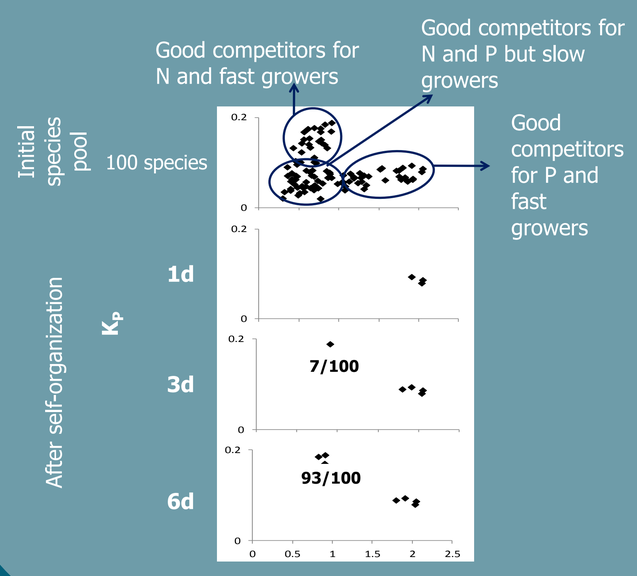
This could indicate that in low frequent pulses, environmental fluctuations allow more species with different traits to co-exist, while in high frequency pulses only few, fast growing species can survive.



Assemblage composition: **Low frequency pulses present higher functional diversity**

A look in species composition of the simulated assemblages at steady-state shows that species with different trends emerge as the frequency of the pulses decreases This is consistent with experimental findings, where more taxonomic groups co-exist as the frequency of the pulses decreases

Model (S3)



Experiment

Initial species pool with numerous taxonomic groups

1d: 1 taxonomic group
-Diatoms

3d: 2 taxonomic groups
-Diatoms
-Cryptophytes

6d: 3 taxonomic groups
-Diatoms
-Cryptophytes
-Chlorophytes

Conclusions

✓Disturbances lead to distinct phytoplankton assemblages

✓Increase in species richness and functional diversity with decreased disturbance frequency

✓Species should be superior competitors for two life-history traits

✓Important traits: High growth rate and competitive ability for PO_4

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