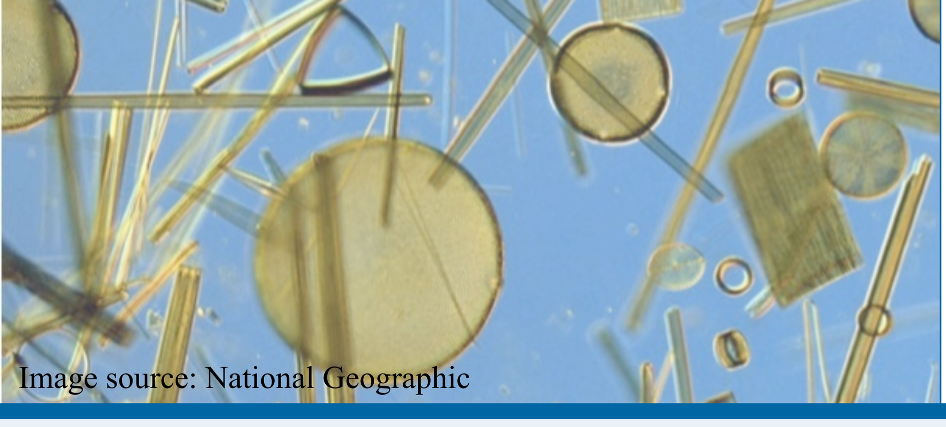


Stoichiometry is crucial for modelling phytoplankton coexistence

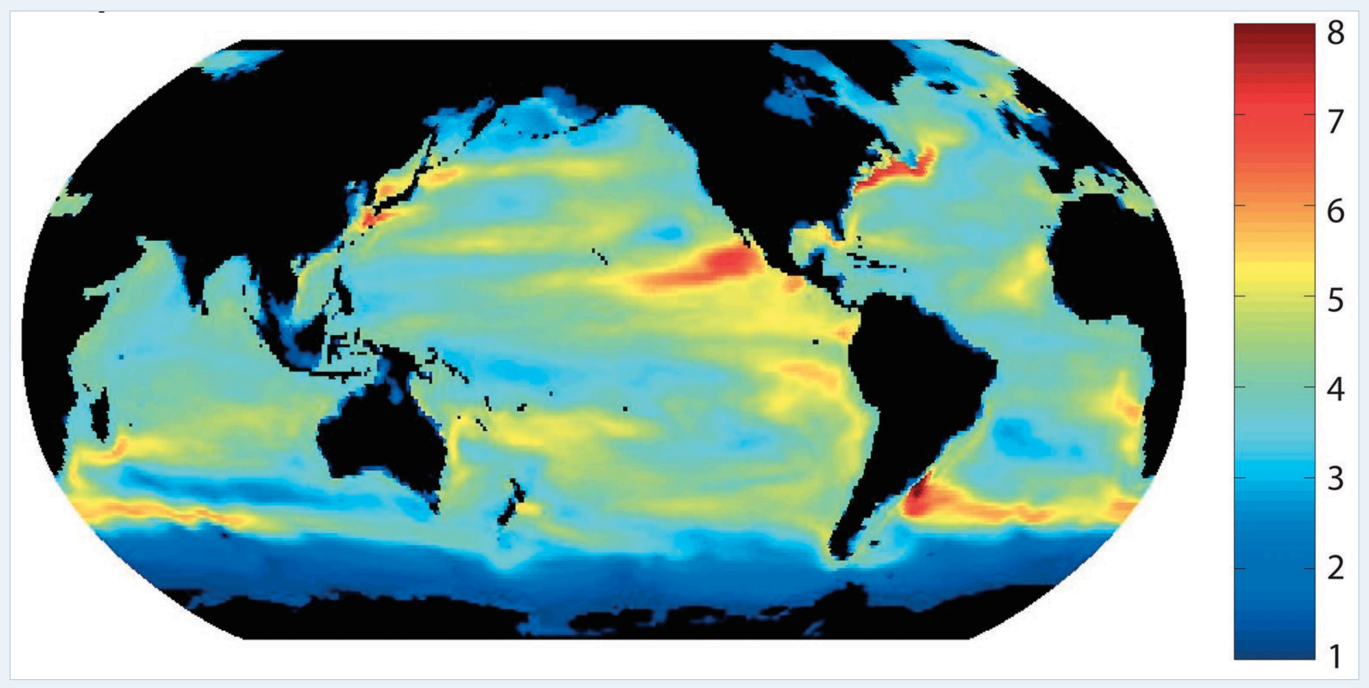
Lena Göthlich, Andreas Oschlies

IFM-GEOMAR, Leibniz-Institute of Marine Sciences (at Kiel University)

Introduction

In marine biogeochemical models, which commonly assume identical elemental composition (stoichiometry), only few phytoplankton species coexist.

Resource competition theory predicts that the maximum possible species number = resource number. Diversity in biogeochemical models is often lower.



Global map of annual average of modelled phytoplankton species no. in the upper 260m, in a model with ~4 resources (Barton et al. 2010).

Objectives

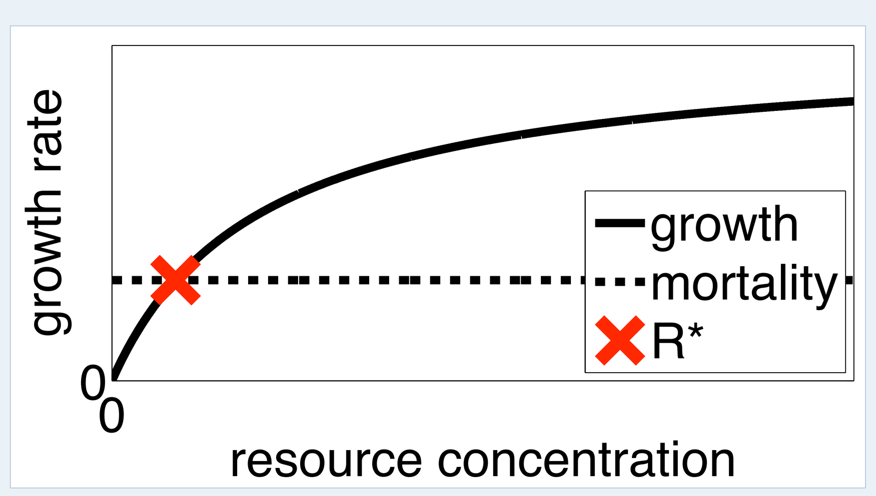
1. Explain low diversity in models with multiple limiting resources
2. Model simple chemostat with stable species number = number of limiting resources.

Methods

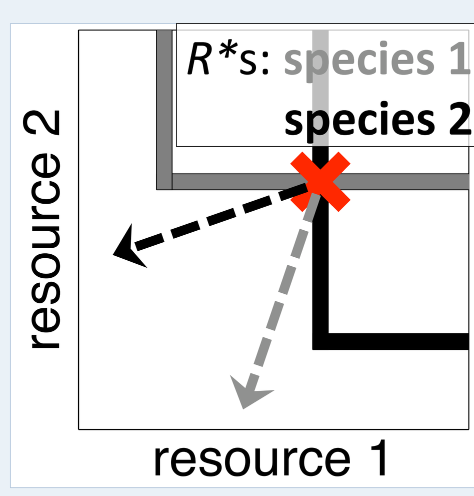
We used a chemostat model of resource competition where (1) growth = nutrient uptake (defined by stoichiometry) and (2) growth is determined by only the most limiting nutrient (Petersen 1975).
The model was run for 20 years with 8 initial species on 4 resources.

Resource competition theory

In equilibrium, the limiting nutrient is depleted to the lowest concentration allowing for survival (*R**), where growth = mortality:



Coexistence on two resources **requires that each species is limited by a different resource** (*R**s intersect, Tilman 1980).



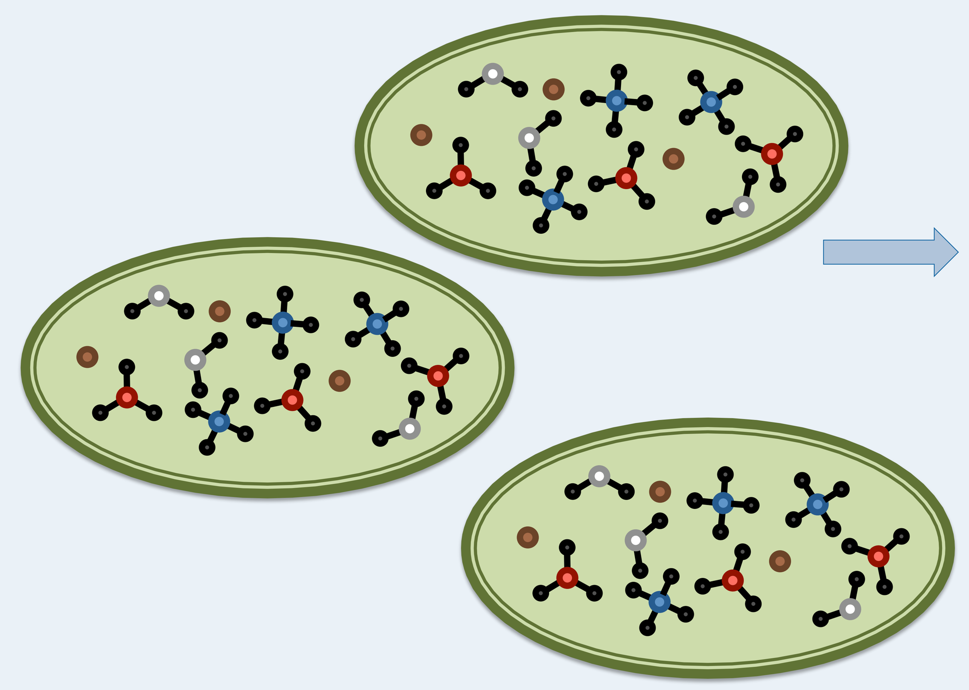
Equilibrium coexistence (x) on two resources is stable if each species consumes more of the resource by which it is limited (see consumption vectors = stoichiometry).

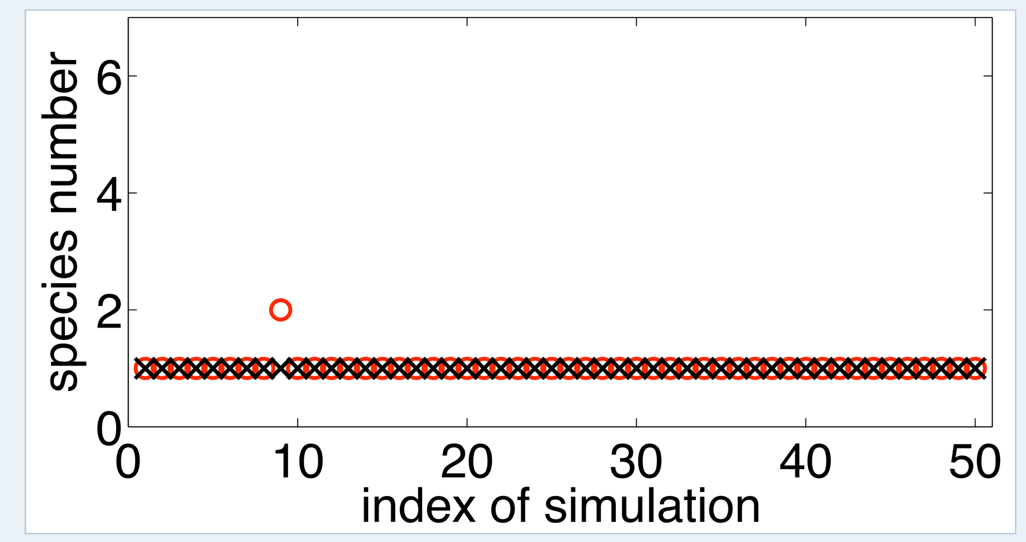
If multiple species are limited by one resource, only the species with the lowest *R** prevails.

Acknowledgements
Research was funded through WGL PAKT, project TiPI (www.pik-potsdam.de/research/research-domains/earth-system-analysis/projects/tipi).

Results

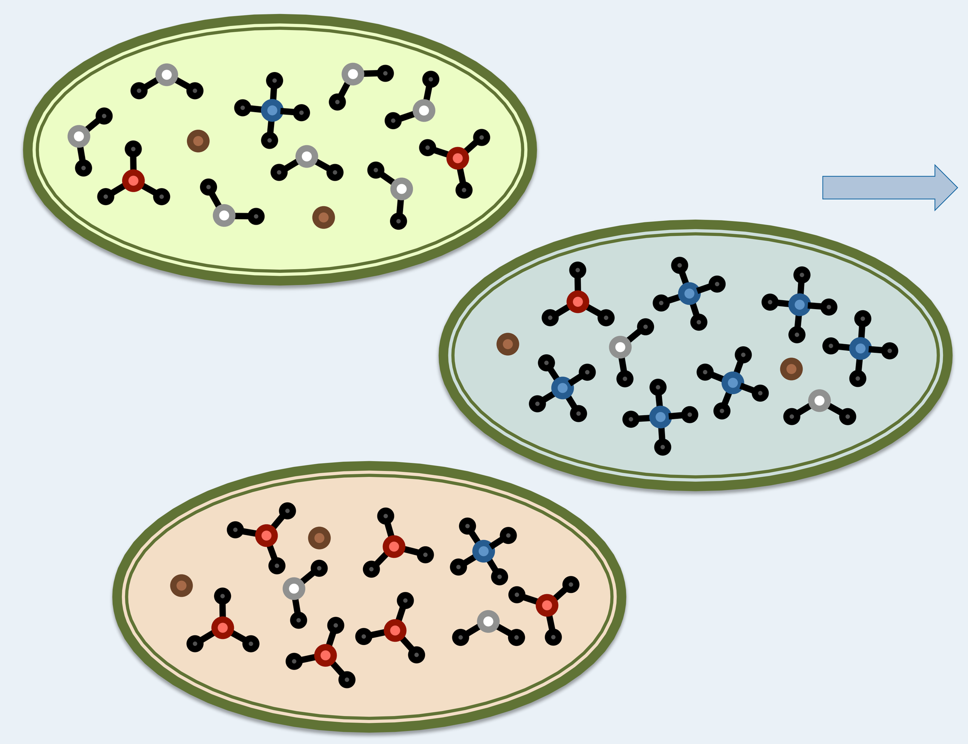
Identical stoichiometry impedes diversity

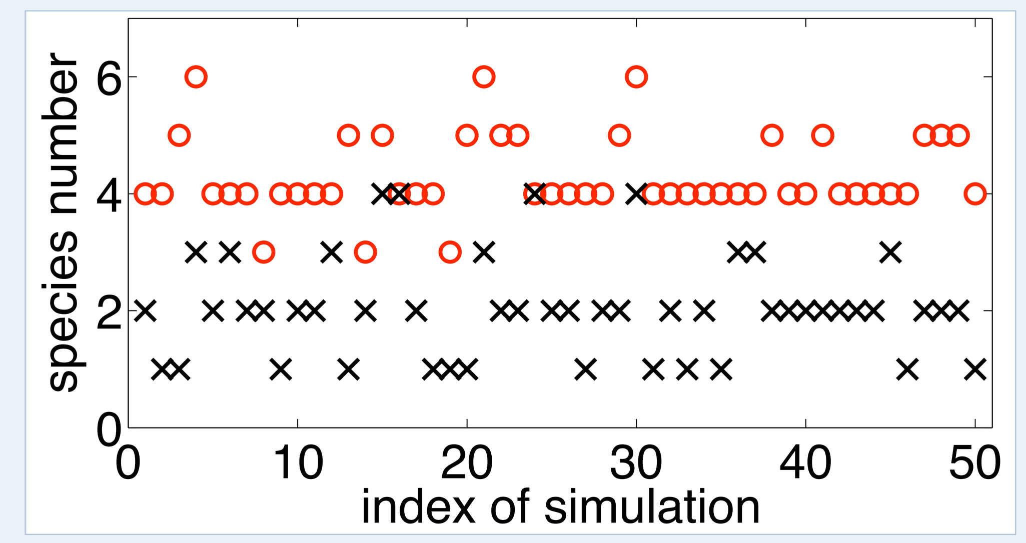




Number of surviving species after a 20 year simulation with identical stoichiometry for all species and *R**s varying randomly (**x**) or ranked according to the equilibrium condition (**o**) derived by Petersen (1975): Each species is limited by a different resource.

Varied stoichiometry allows for diversity





Number of surviving species after a 20 year simulation with stoichiometry assigned such that each species consumes/contains most of its limiting resource (Huisman & Weissing 2001). *R**s vary randomly (**x**) or ranked according to the equilibrium condition (**o**).

Where species number exceeds resource number, competitive exclusion is not yet complete.

Ecological niche

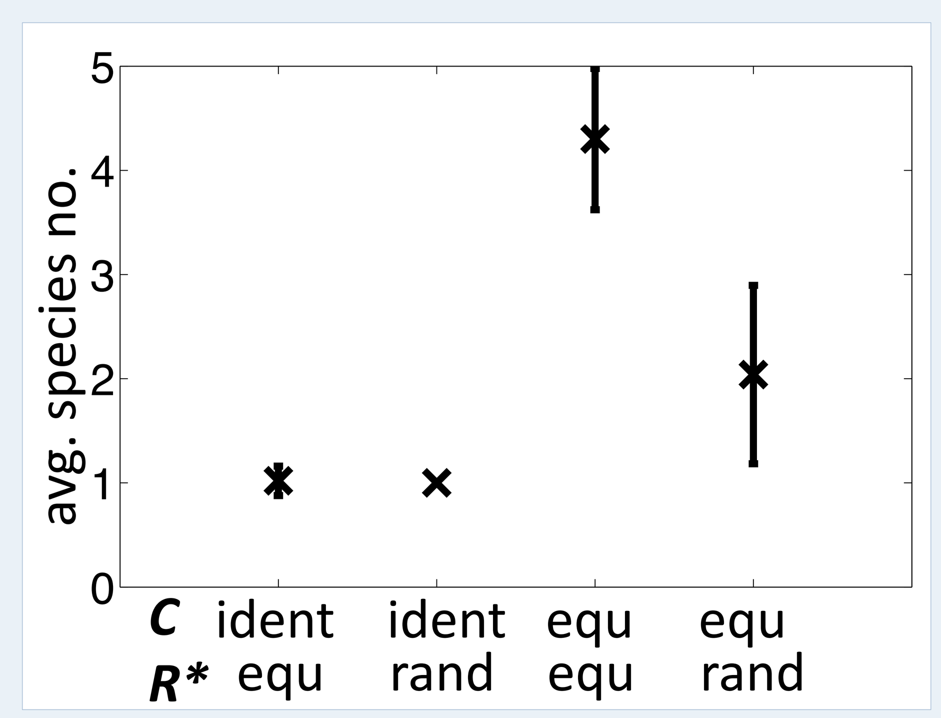
In theoretical ecology, the **requirement niche** is the response of an organism to its environment (***R****). The **impact niche** is the impact an organism has on its environment (**stoichiometry**).

This study shows that both niches need to differ between species to allow for stable coexistence. Ranking the ***R*s*** such that each species is limited by a different resource is a prerequisite for the **existence of a multi-species equilibrium**.

Assigning the **stoichiometry** such that each species consumes most of its limiting resource ensures the **stability of a given equilibrium.**

Conclusion

Identical stoichiometry ("*C*"s, 1st & 2nd from left), as commonly used in marine biogeochemical models, **impedes diversity** irrespective of the way the *R**s are assigned.



Using **stoichiometry according to equilibrium conditions** (3rd & 4th) increases the **chance for diversity**, even with randomly assigned *R**s.

Outlook

Run global model with varied stoichiometry to test applicability of results in more realistic environment.

References

- Barton AD, Dutkiewicz S, Flierl G, Bragg J, Follows M (2010) Patterns of Diversity in Marine Phytoplankton. *Science*
- Huisman J, Weissing F (2001) Biological conditions for oscillations and chaos generated by multispecies competition. *Ecology*
- Leibold M (1995) The niche concept revisited: mechanistic models and community context. *Ecology*
- Petersen R (1975) The paradox of the plankton: An equilibrium hypothesis. *Am. Nat.*
- Tilman D (1980) Resources: a graphical-mechanistic approach to competition and predation. *Am. Nat.*

IFM-GEOMAR
Düsternbrooker Weg 20
Kiel, Germany
lgoethlich@ifm-geomar.de