Theoretical Study on the Effects of Flexible Grazing Preference of Zooplankton on Regulating C:N:P Ratios of Marine Ecosystem

OCB 2017 Summer Workshop
Session: Stoichiometry and higher trophic levels
Wednesday, June 28th, 2017 @WHOI

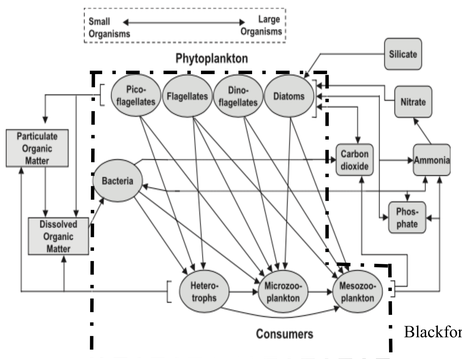
Tatsuro Tanioka* and Katsumi Matsumoto
Department of Earth Sciences, University of Minnesota, Minneapolis, Minnesota, USA (*tanio003@umn.edu)

Introduction

The C:N:P ratios of zooplankton are dependent on their internal regulatory mechanisms, grazing preference, and the C:N:P ratios of their preys. How zooplankton's internal stoichiometry affects the bulk C:N:P ratios of exported organic matter is currently poorly understood, especially when there are multiple preys and predators each with varying internal stoichiometry. The aim of this research is to show how the changes in grazing preference of zooplankton as a function of internal stoichiometry of their prey affects the marine ecosystem dynamics within a simple NPZD type model with multiple prey and predator functional groups.

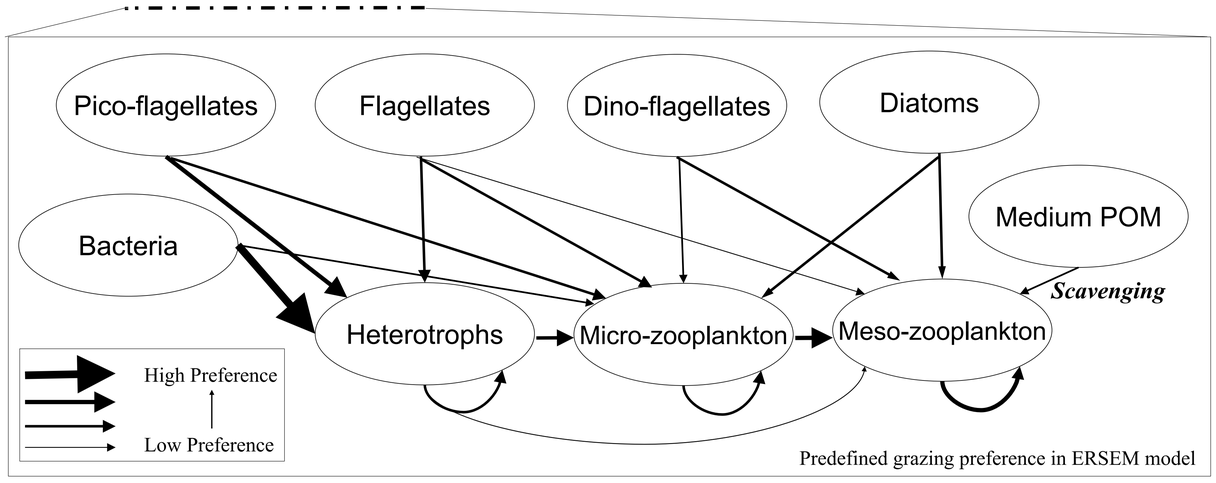
Ecosystem Model

ERSEM (European Regional Seas Ecosystem Model) [1,2]



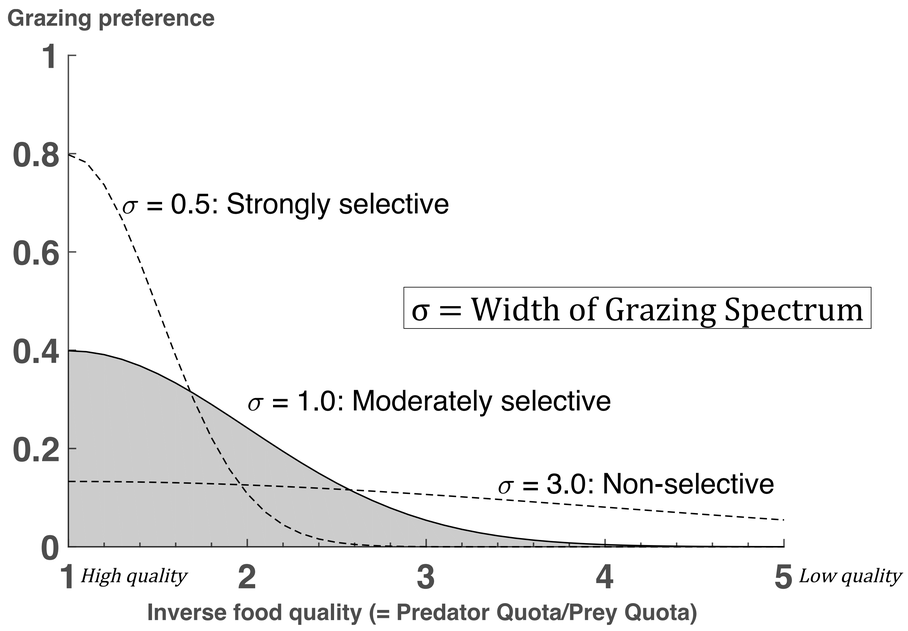
Blackford et al. (2004)

- 4 Phytoplankton functional types (flexible Chl:C:N:P)
- 3 Zooplankton functional types (flexible C:N:P, fixed grazing preference)
- 3 particulate organic matter size classes
- Labile and semi-labile dissolved organic matter
- 3 nutrients (NO_3^-, NH_4^+, PO_4^{3-})



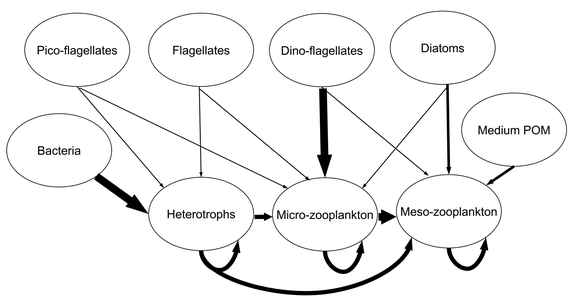
Predefined grazing preference in ERSEM model

What's new? Grazing preference as a function of food quality



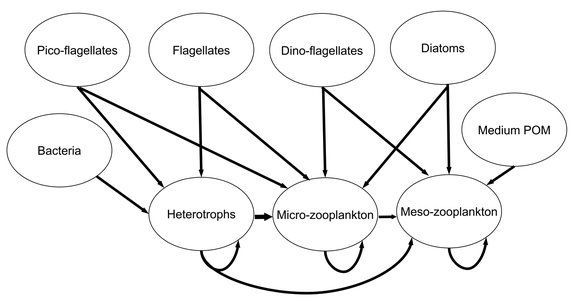
Shift in ecosystem dynamics due to grazing preference (schematic)

Small σ (selective)



- Strong selectivity of prey
- Intra-trophic grazing and cannibalism
- Bottom up ecosystem

Large σ (non-selective)



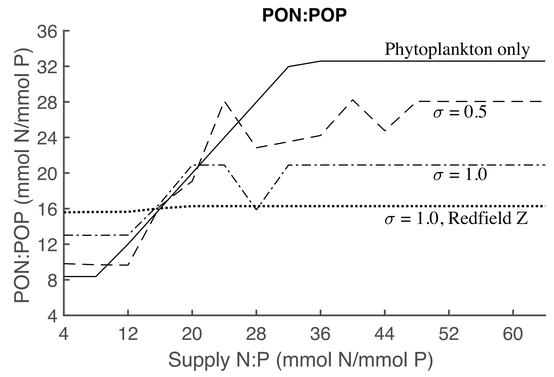
- Smaller selectivity of prey
- Inter-trophic grazing
- Top down ecosystem

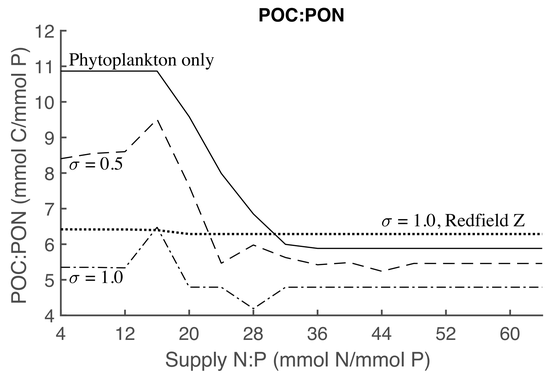
Model setup

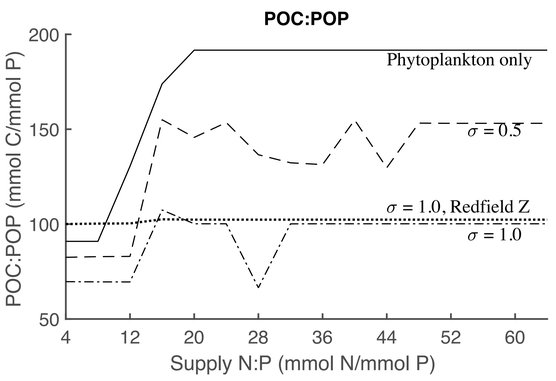
- Zero-dimensional box model under constant light and temperature.
- Varying N:P supply ratio from 4:1 to 64:1 with a constant phosphate influx.
- Run until the system reaches equilibrium.
- Threshold for cannibalism of zooplankton is set at 15% of total cumulative grazing preference.

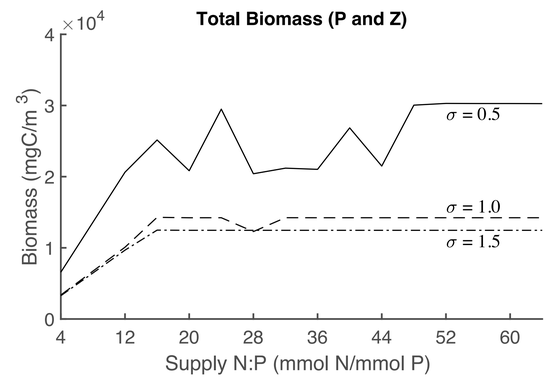
Results and Discussions

POM stoichiometry approaches Redfield Ratios with wider grazing spectrum

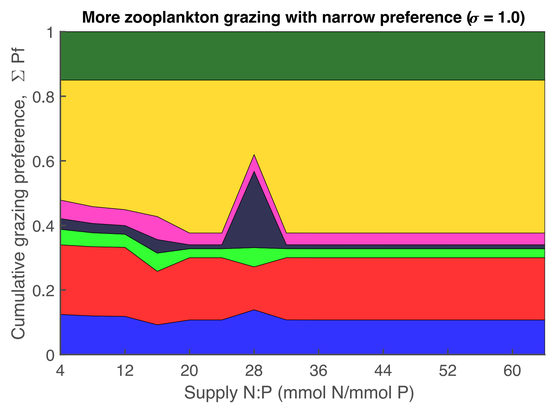


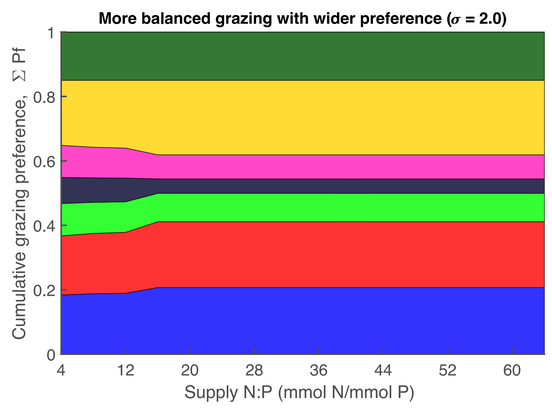


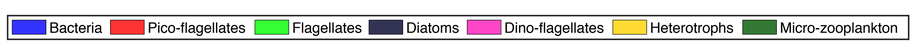




Grazing preference of micro-zooplankton changes with grazing spectrum







1. Strong preference of heterotrophs
2. Intra-trophic grazing and cannibalism
3. Unstable around N:P ~ 24

1. More Balanced preference
2. Pico-flagellates and Bacteria preferred
3. Not affected by N:P supply above ~16

Conclusion

- Food quality-dependent grazing preference can *dynamically* shift the ecosystem between a stable bottom-up system (i.e., phytoplankton dominated) and a stable top-down ecosystem (i.e., biomass and C:N:P ratios regulated by zooplankton) with an unstable transitional state.
- Grazing preference of zooplankton, which is currently fixed *a priori* in most models, can be quite variable and thus have significant impacts on the food-web and carbon cycle.

Reference

1. Blackford, J. C., J. I. Allen, and F. J. Gilbert (2004), Ecosystem dynamics at six contrasting sites: A generic modelling study, *J. Mar. Syst.*, *52*(1–4), 191–215, doi:10.1016/j.jmarsys.2004.02.004.
2. Butenschön, M. et al. (2016), ERSEM 15.06: A generic model for marine biogeochemistry and the ecosystem dynamics of the lower trophic levels, *Geosci. Model Dev.*, *9*(4), 1293–1339, doi:10.5194/gmd-9-1293-2016.