Model: Phosphorus uptake by microbes from cruises in the Sargasso Sea; Bermuda Atlantic Time-Series Station from 2006-2013 (Biological C:N:P ratios project)

Website: https://www.bco-dmo.org/dataset/540481
Version: 2014-11-24

Project
» Biological Controls on the Ocean C:N:P ratios (Biological C:N:P ratios)

Programs
» Dimensions of Biodiversity (Dimensions of Biodiversity)
» Ocean Carbon and Biogeochemistry (OCB)

Contributors	Affiliation	Role
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Dataset Description

The model using this data was discussed in Lomas et al. 2014 PNAS.

Related datasets:
- P-uptake - kinetics
- P-uptake - taxon specific
- P-uptake - bulk
- P-uptake - biogeochemistry

Methods & Sampling

As described in Lomas et al. 2014, a model that considers interactions between ecology and evolution is used with the aim of replicating the cruise data contained in this project's database. The model consists of an ecological model that combines the classic Droop model for cell growth with a mechanistic representation of phytoplankton's ability to regulate the number of proteins used for nutrient uptake, positively correlated with maximum uptake rate. Size is chosen as adaptive trait, as size is linked to all the key traits in this trait-based representation.

For each species to be replicated, a specific allometry for half-saturation constant and maximum growth rate is chosen. Thus, each species (or, more generally, ecotype or functional group) is characterized by fixed parameters for these two allometries (see model database). Different chemostat conditions (i.e. dilution rates) are used to simulate different locations.

For each location, an initial ecotype reproduces, and mutations are allowed. As time goes by, more and more mutants co-exist temporarily, with continuous alternation in dominance and extinctions, and ecological responses (plasticity, i.e. changes in the number of uptake proteins) and adaptive responses (i.e. mutations) occurring simultaneously. After a transient, the population finds a strain that dominates over any other possible strain, or in other words, the system reaches the evolutionary stable strategy for size. When that happens, the simulation stops, and the uptake-related observables of that strain are selected as potential representative of that location; a series of replicates per location is necessary, due to the stochastic nature of the adaptive process (see ecolutionary-simulation entries in the model database). Use uptake rate for each location and phosphate availability in the database to replicate Fig.4 in main text of Lomas et al 2014.

For the kinetic data (and Fig.S5 in the mentioned paper), a representative size is chosen per species that is to be replicated. Then, different dilution rates allow for increases in stationary nutrient concentrations.

Taxon	Allometry	a	b	Units
Prochlorococcus	K=a*size^b	3.98E+00	3.00E-01	nmol/l
	mu_max=a*size^b	7.50E-01	-3.00E-01	1/d
Synechococcus	K=a*size^b	3.98E+00	3.00E-01	nmol/l
	mu_max=a*size^b	3.00E+00	-3.00E-01	1/d
PicoEukaryotes	K=a*size^b	2.00E+00	5.60E-01	nmol/l
	mu_max=a*size^b	1.50E+00	-2.00E-01	1/d
NanoEukaryotes	K=a*size^b	2.00E+00	5.60E-01	nmol/l
	mu_max=a*size^b	8.00E+00	-2.00E-01	1/d

Data Processing Description

In order to obtain one representative per replicate of the evolutionary simulations, an average over replicates was measured, for each of the variables depicted in the table above and associated data file.

BCO-DMO Processing Notes:
- added conventional header with dataset name, PI name, version date
- renamed parameters to BCO-DMO standard
- replaced spaces and other special characters with underscore
- revised the data to include cell sizes for the kinetic simulation; removed cell size column from table in the metadata. This replaces data from 2014-11-17.

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Data Files

File
Puptake_model.csv (Comma Separated Values (.csv), 10.55 KB) MD5:ba09115a95206ad94cd4aa6135156abe Primary data file for dataset ID 540481

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Parameters

Parameter	Description	Units
model_description	description of the model	unitless
taxon	taxonomic name of group used in model	unitless
dilution_rate	dilution rate	dilutions/day
size_cell	cell volume	microm^3
PO4	phosphate concentration	moles/liter
P_uptake_rate	phosphate uptake rate	moles/day
growth_rate_realiz	realized growth rate	growth/day
P_uptake_rate_max	maximum phosphate uptake rate	moles/liter/day
K_effective	Phosphate half-saturation constant	moles/liter

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Deployments

AE1206

Website	https://www.bco-dmo.org/deployment/58935
Platform	R/V Atlantic Explorer
Start Date	2012-03-14
End Date	2012-03-23
Description	AE1206 was the third in a series of four cruises for the Trophic BATS project. On each cruise, sampling was conducted at three stations: the center and edge of a mesoscale eddy and at one station outside of the eddy. Core CTD casts to ~2000 meters and pre-dawn 'Productivity' CTD casts were made at each station. Cruise information and original data are available from the NSF R2R data catalog.

AE1319

Website	https://www.bco-dmo.org/deployment/537979
Platform	R/V Atlantic Explorer
Report	http://dmoserv3.whoi.edu/data_docs/Bio_CNP_Ratios/AE1319_Cruise_Report_09182013_reduced2.pdf
Start Date	2013-08-14
End Date	2013-09-11
Description	Cruise for project 'Dimensions of Biodiversity: Biological Controls on the Ocean C:N:P ratios'.

AE1123

Website	https://www.bco-dmo.org/deployment/538493
Platform	R/V Atlantic Explorer
Start Date	2011-09-27
End Date	2011-10-19
Description	Lomas_BATS_validation_2011: sampling for nutrient study

AE0810

Website	https://www.bco-dmo.org/deployment/58062
Platform	R/V Atlantic Explorer
Start Date	2008-05-03
End Date	2008-05-25
Description	One in a series of transect cruises to study the biological and biogeochemical aspects of the marine phosphorus cycle. Note the cruise identifiers for the Atlantic Explorer were originally formatted as XYY## (e.g. X0806 was the 6th cruise in 2008). The data files include cruise IDs of this type. The vessel operator changed the cruise ID syntax several years after the cruise and the official cruise ID syntax was changed to AEYY##. For example, AE0810 should be the same cruise as X0810. One exception for this dataset is that X0804 is cruise ID AE0810 (unclear how the cruise numbering scheme got so confused). Database validation showed that AE0804 was not the correct cruiseid based on information at R2R. The cruiseid was then updated to reflect the corrected information (the May 2008 cruise was AE0810. Additional Information from R2R Site

BVAL37

Website	https://www.bco-dmo.org/deployment/540202
Platform	R/V Atlantic Explorer
Start Date	2006-10-18
End Date	2006-10-29
Description	BATS Validation stations

BVAL39

Website	https://www.bco-dmo.org/deployment/538365
Platform	R/V Atlantic Explorer
Start Date	2007-10-21
End Date	2007-10-29
Description	BATS Validation stations

X0606

Website	https://www.bco-dmo.org/deployment/58060
Platform	R/V Atlantic Explorer
Start Date	2006-05-19
End Date	2006-05-27
Description	One in a series of transect cruises to study the biological and biogeochemical aspects of the marine phosphorus cycle.

X0619

Website	https://www.bco-dmo.org/deployment/540209
Platform	R/V Atlantic Explorer
Start Date	2006-11-21
End Date	2006-11-22

X0705

Website	https://www.bco-dmo.org/deployment/58061
Platform	R/V Atlantic Explorer
Start Date	2007-06-02
End Date	2007-06-14
Description	One in a series of transect cruises to study the biological and biogeochemical aspects of the marine phosphorus cycle.

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Project Information

Biological Controls on the Ocean C:N:P ratios (Biological C:N:P ratios)

Coverage: western North Atlantic; 60N to 20N along 66W longitude; 20N to 15S in the tropical Pacific

One of the fundamental patterns of ocean biogeochemistry is the Redfield ratio, linking the stoichiometry of surface plankton with the chemistry of the deep ocean. There is no obvious mechanism for the globally consistent C:N:P ratio of 106:16:1 (Redfield ratio), especially as there is substantial elemental variation among plankton communities in different ocean regions. Thus, knowing how biodiversity regulates the elemental composition of the ocean is important for understanding the ocean and climate as a whole -- now and in the future.

The conceptual hypotheses for this study are as follows: 1. The C:N:P ratio of a cell is constrained by its broad taxonomic group, which determines, for example, whether it has an outer shell, its size, functional metabolism, membrane lipid composition. 2. Within a taxon, there is high genetic diversity. Some of this genetic diversity is potentially laterally transferred, or can be lost within taxa, and confers various functional abilities (organic phosphate assimilation, nitrate assimilation, photoheterotrophy, etc.). Functional diversity provides the cell with further flexibility, such as the ability to respond to varying nutrient supply rates/ratios, and affects a cell's C:N:P ratio within the range specified by the taxon. 3. Given these taxonomic and genetic constraints, a cell is physiologically plastic and modifies how it allocates cellular resources in response to nutrient supply rates/ratios in the environment. 4. The microbial diversity (taxonomic, genetic, and functional) of the surface ocean varies over time and space, driven by many factors in addition to nutrients. The sum of this mixture composes the ecosystem C:N:P, the ratio that Redfield described.

Based on this framework, the CoPIs will make field observations of taxon-specific stoichiometry and growth rates, genomic analyses, and conduct laboratory chemostat experiments to improve understanding of how ocean taxonomic, genetic, and functional biodiversity control the stoichiometry of the surface ocean plankton. Their analyses of these data would lead to a mechanistic understanding of variations in the Redfield ratio, both spatially and temporally.

This study will greatly expand knowledge of the genomic diversity among ocean microbes and how this diversity affects biogeochemistry. The stoichiometry of the ocean's microbes is a parameter that nearly every chemical or biological oceanographer uses, from converting measurements made in one element to another, to estimating regional and global nitrogen budgets. The research also has important implications for the global carbon budget and any changes that might result from climate change.

To understand mechanistically temporal and spatial variability of the plankton C:N:P ratio, biodiversity must be studied not only at the traditional taxonomic level, but at the genetic and functional levels which dictate organism response to their environment. Data will be integrated into a combined ocean ecological, evolutionary, and biogeochemical model, with flexible stoichiometry, including cellular biochemical allocations. Seeding a coupled physical-biological model of the oceans with multiple competing genotypes enables the exploration of ecological and evolutionary patterns of resource acquisition and C:N:P ratios. Developing a more mechanistic examination of the course of ecology and evolution, in which laboratory and field data define tradeoffs between different growth and nutrient acquisition strategies, would estabblish the framework of adaptive dynamics for determining "evolutionarily convergence". Finally, model outcomes will be evaluated against field data.

The field work planned for this project includes several cruises: BV46 (September/October 2011), BV48 (September 2012), a June 2013 cruise from Bermuda to the Labrador Sea, and a cruise from Hawaii to Tahiti (May 2014). Additionally, samples will be be acquired during cruises of opportunity.

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Program Information

Dimensions of Biodiversity (Dimensions of Biodiversity)

Website: http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503446

Coverage: global

(adapted from the NSF Synopsis of Program)
Dimensions of Biodiversity is a program solicitation from the NSF Directorate for Biological Sciences. FY 2010 was year one of the program. [MORE from NSF]

The NSF Dimensions of Biodiversity program seeks to characterize biodiversity on Earth by using integrative, innovative approaches to fill rapidly the most substantial gaps in our understanding. The program will take a broad view of biodiversity, and in its initial phase will focus on the integration of genetic, taxonomic, and functional dimensions of biodiversity. Project investigators are encouraged to integrate these three dimensions to understand the interactions and feedbacks among them. While this focus complements several core NSF programs, it differs by requiring that multiple dimensions of biodiversity be addressed simultaneously, to understand the roles of biodiversity in critical ecological and evolutionary processes.

Ocean Carbon and Biogeochemistry (OCB)

Website: http://us-ocb.org/

Coverage: Global

The Ocean Carbon and Biogeochemistry (OCB) program focuses on the ocean's role as a component of the global Earth system, bringing together research in geochemistry, ocean physics, and ecology that inform on and advance our understanding of ocean biogeochemistry. The overall program goals are to promote, plan, and coordinate collaborative, multidisciplinary research opportunities within the U.S. research community and with international partners. Important OCB-related activities currently include: the Ocean Carbon and Climate Change (OCCC) and the North American Carbon Program (NACP); U.S. contributions to IMBER, SOLAS, CARBOOCEAN; and numerous U.S. single-investigator and medium-size research projects funded by U.S. federal agencies including NASA, NOAA, and NSF.

The scientific mission of OCB is to study the evolving role of the ocean in the global carbon cycle, in the face of environmental variability and change through studies of marine biogeochemical cycles and associated ecosystems.

The overarching OCB science themes include improved understanding and prediction of: 1) oceanic uptake and release of atmospheric CO2 and other greenhouse gases and 2) environmental sensitivities of biogeochemical cycles, marine ecosystems, and interactions between the two.

The OCB Research Priorities (updated January 2012) include: ocean acidification; terrestrial/coastal carbon fluxes and exchanges; climate sensitivities of and change in ecosystem structure and associated impacts on biogeochemical cycles; mesopelagic ecological and biogeochemical interactions; benthic-pelagic feedbacks on biogeochemical cycles; ocean carbon uptake and storage; and expanding low-oxygen conditions in the coastal and open oceans.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1046001
NSF Division of Ocean Sciences (NSF OCE)	OCE-1046368
NSF Division of Ocean Sciences (NSF OCE)	OCE-1046297
NSF Division of Ocean Sciences (NSF OCE)	OCE-1045966

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