R code for a model of phytoplankton community structure under multiple frequencies of pulsed nutrient supply.

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Project
» Eating themselves sick? Ecological interactions among a mixotrophic flagellate, its prokaryotic prey, and an ingestible giant virus. (Giant virus ecology)

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Abstract
R code for a model of phytoplankton community structure under multiple frequencies of pulsed nutrient supply.

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Dataset Description

A trait-based approach is used to model how phytoplankton community structure might vary when nutrients are supplied periodically at multiple timescales.

Trait variation across phytoplankton ‘species’ is defined by an empirically supported three-way tradeoff between maximum growth rate, specific uptake affinity for phosphate, and internal storage capacity for phosphorus (Edwards et al. 2013).

400 species varying along on this tradeoff plane are initialized in the community, and competition proceeds, with species at very low abundance removed, until the dynamics converge on a periodic attractor.

The frequency and magnitude of nutrient pulses are varied to investigate how community trait structure and diversity respond. Nutrient pulses are reprented as mixing events with water below the surface mixed layer, which simultaneously dilute the phytoplankton populations. Variations in parameter values and the resulting changes in community structure are described in Smith and Edwards (2019).

Processing Description

BCO-DMO processing notes:

- Linked to the provided R code

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Data Files

File	Version
Phytoplankton_Community_Structure_Rcode_Smith_Edwards_2019 filename: Phytoplankton_Community_Structure_Rcode_Smith_Edwards_2019.R (Octet Stream, 10.34 KB) MD5:08bfe78a634c2d96e6d8d55292db92c2 *R code to model changes in phytoplankton community structure and diversity, based on three traits: maximum growth rate, specific uptake affinity for phosphate, and internal storage capacity for phosphorus. These variables are affected by periodically supplying nutrients at multiple timescales.* *parameter definitions:* *umax = maximum growth rate* *Psaff = scaled uptake affinity for phosphorous* *vmaxhi = maximum cell-specific phosphate uptake rate when quota is at its minimum* *vmaxlo = maximum uptake rate when quota is at its maximum* *K = half-saturation constant for phosphate uptake* *Q = cellular internal phosphorus concentration* *Qmin = minimum phosphorus quota* *u.infin=umax*Qmax/(Qmax-Qmin)=theoretical growth rate at inifinite quota* *m = instantaneous mortality rate* *a = instantaneous mixing rate* *d = effective instantaneous mixing/mortality rate for the pulses* *S = dissolved phosphorus concentration in water below the mixed layer* *f = proportion of phosphorus in dead cells that is instantly remineralized*	1

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Related Publications

Edwards, K. F., Klausmeier, C. A., & Litchman, E. (2013). A Three-Way Trade-Off Maintains Functional Diversity under Variable Resource Supply. The American Naturalist, 182(6), 786–800. doi:10.1086/673532
Results

Smith, A. N., & Edwards, K. F. (2019). Effects of multiple timescales of resource supply on the maintenance of species and functional diversity. Oikos, 128(8), 1123–1135. doi:10.1111/oik.04937
Results

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Parameters

Parameters for this dataset have not yet been identified

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Project Information

Eating themselves sick? Ecological interactions among a mixotrophic flagellate, its prokaryotic prey, and an ingestible giant virus. (Giant virus ecology)

Coverage: North Pacific Subtropical Gyre - Station ALOHA; and North Pacific tropical embayment, Oahu, HI - Kaneohe Bay

NSF Award Abstract:
Phytoplankton support the biological bounty of our seas, so understanding what controls their growth and death is one of the central issues in oceanography. In much of the nutrient-depleted surface waters of the open ocean, the most successful phytoplankton are tiny photosynthetic bacteria known as Prochlorococcus. These bacteria are highly successful competitors for the ocean's limited nutrients and commonly outcompete larger phytoplankton. Yet, many larger types of phytoplankton persist in the ocean. One reason why this coexistence may occur is that some of the weaker competitors called mixotrophs have evolved a clever alternative strategy best summed up as "If you can't beat them, eat them". In addition to directly competing for nutrients dissolved in the water, these larger phytoplankton can acquire nutrients by consuming and digesting their smaller rivals. The dual ability to photosynthesize and eat competitors has clear advantages, but there can be hidden costs of this intraguild predation strategy. While feeding on Procholorococcus, mixotrophs may also inadvertently ingest giant viruses that are so large they are mistaken for food. Infection is often fatal. Mixotrophy and viral infection are ubiquitous in the ocean; however these processes are often understudied and missing from traditional models of marine food webs that generally consider photosynthesis and predation independently. In this project, the interactions among a common mixotroph (Florenciella), its prey (Prochlorococcus), and a virus that infects the mixotroph (FloV1) will be studied in the lab and field. This research will also help guide the development of a cohesive mixotroph-virus-prey trophic model. Improving these trophic models to account for more complex processes could fundamentally change our understanding of marine trophic dynamics. The project will directly support the training of a post-doc, graduate and undergraduate student in inter-disciplinary science that includes field, lab, and modeling activities. The project will support a major component of the graduate student's dissertation and the progressive training of an undergraduate student, culminating in an independent project. The concepts of mixotrophy and viral ecology investigated here will be translated into a public display seen by hundreds of children and members of the public. The PIs will engage a K-12 teacher in the fieldwork at sea through a "Science Teachers Aboard Research Ships (STARS)" program and will recruit an undergraduate researcher through the CMORE Scholars program at the University of Hawaii.

The advantages and drawbacks of a mixotrophic strategy will depend on the availability of resources and competitors and the likelihood of viral infection. The timing of grazing will be tested to determine whether Florenciella grazes continuously or separates it grazing and photosynthetic activities by only feeding at night. Prey preferences of Florenciella will be tested in competitive grazing experiments offering Prochlorococcus as prey in the presence of varying amounts of other bacteria and cyanobacteria. Electron microscopy will be used to determine whether prey and virus enter Florenciella by the same pathway and whether the presence of prey competitively interferes with viral infection. The kinetics of grazing by Florenciella and infection of Florenciella by FloV1 will be quantified. The results from these lab experiments will be used to parameterize a numerical model. The model will be used to answer questions and make predictions about the dynamics of the mixotroph-virus-prey system and those predictions will be compared to field data. Collectivity, these observational, experimental and quantitative analyses will provide a detailed exploration of the ecological complexity hidden at the base of the marine food web.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1559356

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