Phytoplankton succession explains size-partitioning of new production following upwelling-induced blooms

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Introduction

Coastal upwelling areas are highly variable ecosystems which play a key role in global fisheries thanks to intermittent episodes of high primary production, mostly caused by large or chain-forming diatoms (1). Global biogeochemical models, such as the Tracers Of Phytoplankton with Allometric Zooplankton (TOPAZ) model (2, 3), are often tailored to represent open ocean systems. They generally perform poorly in reproducing the bursts of high chlorophyll observed following upwelling events. We hypothesize that this is because of the inadequate, or lack of, representation of these bloom forming large phytoplankton. In this study (4) we varied the configurations of a modified version of the TOPAZ model as a framework to reproduce the observed patterns and timescales of community succession and size-partitioned new production in mesocosms simulating upwelling-induced blooms (5).



(left and center) Ocean chlorophyll *a* and sea surface temperature from the MODIS Aqua sensor in cold, nutrient-rich upwelling plumes off California (composite 23-30 April 2011) (6).

(right) Bloom-forming diatom species (top) *Chaetoceros debilis*, cell size 8-40 µm, and *Thalassiosira anguste-lineata*, cell size 14-80 µm, dominated the plankton community biomass at the end of the mesocosm experiment (5) (micrographs courtesy of (7))

Results

The most parsimonious model configuration having the best fit with observations, in terms of timescale and size-partitioning of new production, was obtained using an optimized, carbon-specific maximum photosynthesis rate (P_{Cmax}) for each of three phytoplankton size-groups (see table and (4)). The original parametrization caused very rapid nutrient exhaustion and the "one-size-fits-all" P_{Cmax} configuration could not reproduce the patterns of size-partitioned new production.

Comparison between model output and mesocosm observations: Specific NO₃⁻ uptake rate

Conclusions & Perspectives

- Size group-specific P_{Cmax} is critical to represent biomass size structure succession. • Large diatoms dominate through early, sustained high relative specific NO⁻ uptake rate.
- Model representation of nutrient acclimation or diatom diversity was not essential.
- We will apply these findings in a high spatial resolution model of an upwelling region to simulate characteristic [Chl*a*] >5 mg m⁻³, using the Carbon, Ocean Biogeochemistry and Lower Trophics (COBALT) model (8).





normalized to total com-

-**--** >20 µ m

📥 5-20 µm

-∎- 0.7-5 µ]m

munity's rate (=1)

2.5

1.5

Comparison between different model configurations. Normalized cumulative error (Σ NRMSE) and optimised parameter values of P_{Cmax} and γ_{Nutmem} for each phytoplankton size group (± 1 SD of bootstrapping, n=500).

model configuration	ΣNRMSE	maximum carbon-specific rate of photosynthesis 10 ⁵ P _{Cmax} at 0°C (s ⁻¹)			
		$P^{S} (<5 \mu m)$	P^{M} (5-20 μm)	$P^{L(r)}$ (>20 μm)	P^{LK} (>20 μ m)
a. 1 P _{Cmax}	3.49 ± 0.47	0.45 ± 0.04	0.45 ± 0.04	0.45 ± 0.04	-
b . 3 P _{Cmax}	2.75 ± 0.23	0.39 ± 0.07	0.46 ± 0.11	0.54 ± 0.08	-
c . 3 P _{Cmax} & nutrient acclimation	2.66 ± 0.23	0.49 ± 0.06	0.53 ± 0.10	0.67 ± 0.06	-
d . 3 P _{Cmax} & 2 P ^L groups	2.77 ± 0.29	0.39 ± 0.07	0.46 ± 0.11	0.83 ± 0.08	0.35 ± 0.03
	acclimation rate γ_{Nutmem} (d ⁻¹)				
		P^{S} (<5 μ m)	P^{M} (5-20 μ m)	P^{L} (>20 μm)	

c. 3 P_{Cmax} & nutrient acclimation 2.66 \pm 0.23 1.0 ± 0.6 1.5 ± 0.6 1.8 ± 0.8

Methods

 Integration of phytoplankton mesocosm experiment (i.e. initial conditions) with TOPAZ biogeochemical model.

Interactions of nitrogen state variables in the modified TOPAZ model





• Testing model configurations after optimization of most sensitive variables, P_{Cmax} and $\gamma_{\text{Nutmem'}}$ to fit observations.

Mesocosm upwelling simulation a.k.a. parking lot oceanography



Citations:

(1) Lassiter *et al.* (2006) Deep Sea Res. II, DOI: 10.1016/j.dsr2.2006.07.013; (2) Dunne *et al.* (2005) Glob. Biogeochem. Cycle, DOI: 10.1029/2004gb002390; (3) Dunne et al. (2013) J. Climate, DOI: 10.1175/jcli-d-12-00150.1; (4) Van Oostende et al. (2015) J. Mar. Sys., DOI: 10.1016/j.jmarsys.2015.01.009; (5) Fawcett & Ward (2011) Mar. Ecol-Prog. Ser., DOI: 10.3354/meps09070; (6) MODIS-Aqua Ocean Color Data; NASA Goddard Space Flight Center, Ocean Ecology Laboratory, Ocean Biology Processing Group. http://dx.doi.org/10.5067/AQUA/MODIS_OC.2014.0 Accessed on 09/27/2015 ; (7) The Phytoplankton Encyclopaedia Project 2012; Creative Commons Attribution-NonCommercial-NoDerivs 3.0 Unported License ; (8) Stock et al., 2014. Prog. Ocean. DOI: 10.1016/j.pocean.2013.07.001

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link to paper (4)

