# Integrating ecology and evolution to study hypothetical dynamics of algal blooms and Muller's ratchet using Evolvix

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## Abstract

Algal blooms have been the subject of considerable research as they occur over various spatial and temporal scales and can produce toxins that disrupt their ecosystem. Algal blooms are often governed by nutrient availability however other limitations exist. Algae are primary producers and therefore subject to predation which can keep populations below levels supported by nutrient availability. If algae as prey mutate to gain the ability to produce toxins deterring predators, they may increase their survival rates and form blooms unless other factors counter their effective increase in growth rate. Where might such mutations come from? Clearly, large populations of algae will repeatedly experience mutations knocking-out DNA repair genes, increasing mutation rates, and with them the chance of acquiring *de-novo* mutations producing a toxin against predators.

We investigate this hypothetical scenario by simulation in the Evolvix modeling language. We modeled a sequence of steps that in principle can allow a typical asexual algal population to escape predation pressure and form a bloom with the help of mutators. We then turn our attention to the unavoidable side effect of generally increased mutation rates, many slightly deleterious mutations. If these accumulate at sufficient speed, their combined impact on fitness might place upper limits on the duration of algal blooms. This requires the following steps:

(1) Random mutations result in the loss of DNA repair mechanisms.
(2) Increased mutation rates make it more likely to acquire the ability to produce toxins by altering metabolism.
(3) Toxins deter predators providing algae with growth advantages that can mask linked slightly deleterious mutational effects.
(4) Reduced predation pressure enables blooms if algae have sufficient nutrients.
(5) Lack of recombination results in the accumulation of slightly deleterious mutations as predicted by Muller's ratchet.
(6) If fast enough, deleterious mutation accumulation eventually leads to mutational meltdown of toxic blooming algae.
(7) Non-mutator algal populations are not affected due to ongoing predation pressure.

Our simulation models integrate ecological continuous-time dynamics of predator-prey systems with the population genetics of a simplified Muller's ratchet model using Evolvix. Evolvix maps these models to Continuous-Time Markov Chain models that can be simulated deterministically or stochastically depending on the question. The current model is incomplete; we plan to investigate many parameter combinations to produce a more robust model ensemble with stable links to reasonable parameter estimates. However, our model already has several intriguing features that may allow for the eventual development of observation methods for monitoring ecosystem health.

*Our work also highlights a growing need to simulate integrated models combining ecological processes, multi-level population dynamics, and evolutionary genetics in a single computational run.*

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An earlier version of this abstract was presented as a poster at the 2017 Mutational Load Symposium held at the International Conference of the Society for Molecular Biology and Evolution (SMBE), 2017 July, 2-6th, Austin, Texas (see http://www.smbe2017.org/). We are continuing to develop this model, so updates will follow eventually.