Prey Toxicity, Prey Refuge Use, and Stochasticity Increase Algal Blooms in a Phytoplankton-Zooplankton Mathematical Model

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Abstract

Phytoplankton blooms are becoming more and more frequent around the globe, producing harmful conditions that can negatively impact people, freshwater and marine ecosystems, and even national economies. These blooms are impacted by the strong relationship between phytoplankton, the prey, and zooplankton, the predator, but it is more than a simple predator-prey relationship. Phytoplankton can use refuges, which have the capacity of protect a constant number of its population from consumption, and can also release toxins that can be detrimental to zooplankton. To study these effects, we have chosen a two-dimensional deterministic model based on the predator-prey relationship between phytoplankton and zooplankton [1], considering each of the three Holling functional responses in predator-prey interactions. In our analysis, we quantified the effects of toxicity, refuge size, and functional response on the presence of phytoplankton blooms and the impact of stochasticity (environmental variability) on these blooms. Numerical simulations show that solutions of all functional responses present stable equilibria, with similar responses between type II and III functional responses. For a wide range of toxicity and refuge size, phytoplankton reached their carrying capacity and zooplankton went extinct. In the predator-prey system with type I functional response, phytoplankton densities increased with toxicity and refuge size, whereas zooplankton densities initially persisted but declined towards extinction. When we incorporated stochasticity, the chance of an algae bloom increased as toxicity and refuge proportion increases for all functional responses. As global climate change increases environmental variability, algae blooms may become more frequent and harder to prevent.

References

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