Quantitative Biology > Populations and Evolution

Vertical distribution and composition of phytoplankton under the influence of an upper mixed layer

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The vertical distribution of phytoplankton is of fundamental importance for the dynamics and structure of aquatic communities. Here, using an advection-reaction-diffusion model, we investigate the distribution and competition of phytoplankton species in a water column, in which inverse resource gradients of light and a nutrient can limit growth of the biomass. This problem poses a challenge for ecologists, as the location of a production layer is not fixed, but rather depends on many internal parameters and environmental factors. In particular, we study the influence of an upper mixed layer (UML) in this system and show that it leads to a variety of dynamic effects: (i) Our model predicts alternative density profiles with a maximum of biomass either within or below the UML, thereby the system may be bistable or the relaxation from an unstable state may require a long-lasting transition. (ii) Reduced mixing in the deep layer can induce oscillations of the biomass; we show that a UML can sustain these oscillations even if the diffusivity is less than the critical mixing for a sinking phytoplankton population. (iii) A UML can strongly modify the outcome of competition between different phytoplankton species, yielding bistability both in the spatial distribution and in the species composition. (iv) A light limited species can obtain a competitive advantage if the diffusivity in the deep layers is reduced below a critical value. This yields a subtle competitive exclusion effect, where the oscillatory states in the deep layers are displaced by steady solutions in the UML. Finally, we present a novel graphical approach for deducing the competition outcome and for the analysis of the role of a UML in aquatic systems.

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