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Modeling dynamics of a plankton community using a discrete-time model

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Motivation and Aim: Modeling the dynamics of phytoplankton and zooplankton is an important part of mathematical ecology since plankton is a key component in aquatic ecosystems, as it is food for various animals: from invertebrates and crustaceans to fish and large marine mammals. This study proposes a two-component discrete-time model of a plankton community, describing the features of the development and interaction of phytoplankton and zooplankton. Reason for applying such models is the day-night rhythm. Indeed, many processes occurring in the plankton community are consistent with circadian rhythm, that is, cyclic fluctuations in the intensity of various biological processes due to the alternation of day and night. Most field observations and measurements of plankton have a day step. Also, discrete-time models allow us to describe a delay naturally.
Methods and Algorithms: To describe the dynamics of each species in the community, we use a discrete analog of the Verhulst equation, which allows us to take into account the autoregulation process. The trophic function covers a lower phytoplankton density due to its consumption by zooplankton. The growth and survival rates of zooplankton depend on the success of its feeding. Zooplankton death caused by its high density or a higher concentration of toxic substances released by phytoplankton is included in the limitation processes. The reproduction and survival of zooplankton depend on the abundance of food supply, namely phytoplankton density, which is described by the trophic function. We use the Arditi–Ginzburg response function based on the study [1], in which different trophic functions were identified for experimental estimates of two species of phytophagous rotifers (*Brachionus calyciflorus* and *Philodina acuticornis*). The proposed model is analytically and numerically investigated, including research on stability, the construction of phase and parametric portraits, and bifurcation analysis. The dynamic mode maps is used to study the dynamics modes of the model
Results: The study analyzes scenarios of the transition from stationary dynamics of community to fluctuations for various values of parameters determining the dynamics of phytoplankton and zooplankton and their interaction. The model analysis shows the stability loss of non-trivial fixed point, corresponding to the coexistence of species in the community, can occur via period-doubling bifurcation and the Neimark-Sacker one leading to the emergence of quasi-periodic fluctuations. In the multistability areas, dynamics mode shift is possible due to a change in the initial condition values. The proposed model of the plankton community reveals the occurrence of long-period fluctuations, which are the alternation of peaks and falls in the abundance of species as a result of the “predator-prey” interaction. Such behavior is in good agreement with the hypothesis that blooming species are those able to escape control by microzooplankton

through a combination of predation avoidance mechanisms at the beginning of the bloom [2]. Note that such dynamics occurs without artificially complicating the coefficients and the model [3].

Conclusion: Thus, despite its simplicity, the proposed discrete-time model of plankton community dynamics reveals adequate dynamics of interacting species. This model can be developed using other types of trophic functions with the expansion of the community components by including additional equations in the model.

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