

Plankton dynamics between depth and surface. Can it be bistable?

A. Ryabov*, L. Rudolf, B. Blasius

Theoretical Ecology Group, Institut für Physik der Universität Potsdam, Am Neuen Palais 10, 14469 Potsdam, Germany

* Electronic Address: ryabov@polly.phys.msu.ru

Phytoplankton is the primary producer in almost all aquatic ecosystems and most important to a huge number of different food webs. Phytoplankton growth is controlled by two resources: light coming from the surface and nutrients transported from the bottom. As a result a deep maximum of phytoplankton biomass often occurs in clear waters of the ocean and lakes. For example, in the ocean this maximum can exist between 50 and 100 m, with a peak at approximately 75 m. This phenomenon has been known for more than 40 years, but only in the recent time it got an analytical approach which allowed to understand underlying mechanisms and estimate the main characteristics like the depth of the maximum or the amount of plankton in the water column. It was shown that the dynamics of the plankton society can be written as a system of two integrodifferential equations for plankton and nutrients densities [1, 2].

At the same time experimental data show possibility of surface phytoplankton maximum. Usually this phenomenon is being explained by lack of light in the deep layers. However current theoretical approach does not provide a consistent description of this phenomenon and difference in the conditions leading to forming of the deep or surface chlorophyll maximum. In this work we present analytical and numerical results [3] of generalization of the system considered in [2] for the case of surface mixing layer. This layer can arise in the ocean and lakes due to wind, waving, storm etc. Its depth can vary from 10 m to 200 m and usually it is characterized by much higher value of diffusion. We will show that this layer can strongly influence on the dynamics of the phytoplankton society. We will derive the main conditions leading to the existence of the surface phytoplankton maximum. Moreover we will show that there is a possibility of bistable behavior: in a range of parameters appearing of the deep or surface plankton maximum depends only on the initial distribution and both states are stable. Furthermore outside this range the transient time from an unstable state (e.g. surface phytoplankton maximum) to a stable one (e.g. deep maximum) can be very long.

-
- [1] C.A. Klausmeier, and E. Litchman, *Limnol. Oceanogr.* **46**, 1998-2007 (2001). "Algal Games: The Vertical Distribution of Phytoplankton in Poorly Mixed Water Columns."
 - [2] J. Huisman et. al. *Nature* **439**, 322-325 (2006). "Reduced mixing generates oscillations and chaos in the oceanic chlorophyll maximum."
 - [3] A. Ryabov, L. Rudolf and B. Blasius in preparation