Mathematical analysis on coexistence condition and indirect effects of phytoplankton and bacteria through nutrient recycling

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Abstract

We estimated indirect effects between phytoplankton and bacteria through phosphorus and carbon at the steady state under the coexistence conditions.

It is known that bacteria highly ingest several inorganic nutrients and compete with phytoplankton in inorganic nutrient under certain nutrient condition. Phosphorus is one of the limitig factor for growth of phytoplankton and bacteria. Phytoplankton excrete dissolved extracellular organic carbon (EOC) when phytoplankton is stressed by limiting inorganic nutrient. One of this excretion is surplus of photosynthesis under inorganic nutrient limitation, and bacteria can grow by using it. For the competition between phytoplankton and bacteria through phosphorus, it is suggested that indirect interaction through EOC may lead to mutualistic situation.

In the model ecosystem, the interactions among species such as competition and mutualism are usually expressed by the sign of direct interactions. However, there are no direct interactions between phytoplankton and bacteria, and only indirect interactions such as exploitative competition through phosphorus and indirect effects arisen from carbon flux and nutrient recycling. Therefore, if we try to estimate these indirect interactions, new mathematical framework may be needed. One of that is press perturbation method. This method leads to inflow-sensitivity matrix, and the matrix reflects the difference in biomass at the coexistence steady state.

By using of the above method, we offer the estimation of indirect interaction between phytoplankton and bacteria under the coexistence condition, and show that the mutualistic interaction between phytoplankton and bacteria can be occurred at the coexistence steady state even if they initially compete with each other through inorganic phosphorus.

In this model, we considered phytoplankton limited their growth by light and phosphorus, and bacteria limited their growth by phosphorus and carbon relesed by phytoplankton. This model was also considered the effect that phosphorus with inflow and outflow is recycled by bacterial decomposition. We adopted permanence as the criterion of the species coexistence, and led to the necessary condition to be a permanence in the system.