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Partha Sharathi Dutta, Bob W. Kooi, Ulrike Feudel

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The impact of a predator on the outcome of competition in the three-trophic food web

Partha Sharathi Dutta*,[a], Bob W. Kooi[b], Ulrike Feudel[c]

[a] *Department of Mathematics, Indian Institute of Technology Ropar, Punjab 140 001, India*
[b] *Department of Theoretical Biology, VU University, De Boelelaan 1087, NL 1081 HV Amsterdam, The Netherlands*
[c] *Theoretical Physics/Complex Systems, ICBM, Carl von Ossietzky Universität, PF 2503, 26111 Oldenburg, Germany*

Abstract

We study the effects of predation on the competition of prey populations for two resources in a chemostat. We investigate a variety of small food web compositions: the bi-trophic food web (two resources–two competing prey) and the three-trophic food web (two resources – two prey – generalist predator) comparing different model formulations: substitutable resources and essential resources, namely Liebig's minimum law model (perfect essential resources) and complementary resources formulations. The prediction of the outcome of competition is solely based on bifurcation analysis in which the inflow of resources into the chemostat is used as the bifurcation parameter. We show that the results for different bi-trophic food webs are very similar, as only equilibria are involved in the long-term dynamics. In the three-trophic food web, the outcome of competition is manifested largely by non-equilibrium dynamics, i.e., in oscillatory behavior. The emergence of predator–prey cycles leads to strong deviations between the predictions of the outcome of competition based on Liebig's minimum law and the complementary resources. We show that the complementary resources formulation yields a stabilization of the three-trophic food web by decreasing the existence interval of oscillations. Furthermore, we find an exchange of a region of oscillatory co-existence of all three species in Liebig's formulation by a region of bistability of two limit cycles containing only one prey and the predator in the complementary formulation.

Key words: bifurcation analysis — chemostat — competition — food web reduction — mass balance model

1. Introduction

Competition among different species is an important factor for the assemblage of communities in ecosystems. It is at the core of many fundamental principles of theoretical ecology like

*Corresponding author
Email addresses: parthasharathi@iitrpr.ac.in (Partha Sharathi Dutta), bob.kooi@vu.nl (Bob W. Kooi), ulrike.feudel@uni-oldenburg.de (Ulrike Feudel)