On the impact of interaction functions on foodchain stability

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Foodchain models with constant boundary conditions are often found to approach a steady state in which the species coexist in equilibrium. However, if parameters are changed, sudden, discontinuous transitions to other types of dynamical behaviour may occur. The critical parameter values at which such transitions happen are called bifurcation points. Typical examples of bifurcations are the Hopf bifurcation which corresponds to the transitition from stationary to oscillatory behaviour or the transcritical bifurcation in which two steady states meet and exchange their stability. Many conceptional foodchain models have been proposed [1]. All of these are specific in the sense that a specific functional form of predator-prey interaction is assumed. In this contribution we propose a very general model for foodchains of arbitrary length. The main advantage of the model is that its stability can be analyzed without having to specify the interaction functions in any way. We discuss some general results of the bifurcation analysis, in particular the initial loss of steady-state stability. Most importantly we find that the effect of interaction functions can be measured in terms of a specific parameter that depends on the exact functional form of interactions.

The proposed general model is used to discuss two different properties of food chains. Firstly, we investigate the stability with respect to changes in the nutrient or prey supply. It was first realized by Rosenzweig [2] that increasing the supply of nutrients or prey tends to destabilize simple foodchain models. This "Paradox of Enrichment" is widely believed to occur in simple models independently of the exact shape of the interaction function. We investigate how different functional forms of predator-prey interaction affect the predator's sensitivity. Our analysis reveals that all commonly used functions, i.e. Holling type II functions, behave in a similar way. If these functions are used, enrichment will always have a destabilizing effect on the foodchain. However, the stability properties depend strongly on the exact shape of the interaction function. Realistic interaction functions exist that are of similar shape as the standard functions but correspond to qualitatively different stability properties. We demonstrate an example where these interaction functions may for instance produce large intervals in which enrichment stabilizes the foodchain.

A second important feature of foodchain models is the consideration of the top predator. Its dynamics is usually not explicitly modeled but is taken into account as a parameter, the exponent of closure. High exponents of closure are believed to stabilize the foodchains and prevent the formation of chaos. Using the methods of qualitative analysis we show how this stabilization occurs in tri-trophic foodchains. Furthermore we demonstrate that (although some stabilizing effect remains) a high exponent of closure will in general not prevent the formation of chaotic regions in longer foodchains.

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