Effects of warming and nutrient enrichment on feeding behavior, population stability and persistence of consumers and their resources

Wojciech Uszko

Akademisk avhandling

som med vederbörligt tillstånd av Rektor vid Umeå universitet för avläggande av filosofie doktorsexamen framläggs till offentligt försvar i Lilla Hörsalen (KB3A9), KBC, tisdagen den 20 september, kl. 09:30. Avhandlingen kommer att försvaras på engelska.

Fakultetsopponent: Professor David A. Vasseur, Department of Ecology and Evolutionary Biology, Yale University, New Haven, CT, USA.
Effects of warming and nutrient enrichment on feeding behavior, population stability and persistence of consumers and their resources

Abstract
Consumer-resource interactions are the basic building blocks of every food web. In spite of being a central research theme of longstanding interest in ecology, the mechanisms governing the stability and persistence of consumer-resource interactions are still not entirely understood. In particular, theoretical predictions on consumer-resource stability along gradients of temperature and nutrient enrichment diverge widely and are sometimes in conflict with empirical results. In this thesis I address these issues from the angle of the functional response, which describes a consumer’s feeding rate as a function of resource density. Specifically, I explore mechanistic, nutrient-based consumer-resource interaction models with respect to the influence of feeding behavior (the shape of the functional response), environmental temperature, nutrient enrichment, and resource quality on consumer-resource stability and persistence. In order to parameterize these models I performed extensive laboratory experiments with pairs of freshwater pelagic algae and grazers of the genus Daphnia, which are widespread, ecologically important model organisms.

I found a sigmoidal type III functional response in every studied Daphnia-algae species pair. The exact form of its shape is described by an exponent $b$ which is determined by fitting functional response models to the experimental data. A high value of $b$ can stabilize consumer-resource systems under the otherwise destabilizing influence of nutrient enrichment, as predicted by a novel stability criterion relating $b$ to the consumer’s prey handling time, food conversion efficiency and mortality. Estimated parameter values and, consequently, stability predictions are sensitive to the method of parameter estimation, and I propose a new estimation procedure that minimizes parameter uncertainty. Because many consumers’ feeding rates depend on temperature, warming is expected to strongly affect food web stability. In functional response experiments over a broad temperature gradient, I found that the attack rate coefficient and the maximum ingestion rate of Daphnia are hump-shaped functions of temperature. Moreover, the functional response exponent increases with warming towards stronger type III responses. Plugging these findings into a nutrient-based consumer-resource model, I found that predator persistence is a U-shaped function of temperature in nutrient enrichment-temperature space. Enrichment easily turns the system unstable when the consumer has a type II response, whereas a type III response opens up a large region of stability at intermediate, for the consumer optimal, temperatures. These findings reconcile seemingly conflicting results of earlier studies of temperature effects on consumer-resource dynamics, which can be mapped as special cases onto the enrichment-temperature space. I finally demonstrate the utility of three key model ingredients - temperature dependence of rate parameters, a mechanistic description of the dynamics of algal resources, and a type III functional response in Daphnia - by successfully implementing them in the description and explanation of phytoplankton-Daphnia dynamics in a mesocosm experiment exploring effects of warming on the spring succession of the plankton.

Keywords
consumer-resource, Daphnia, functional response, nutrient enrichment, parameter estimation, persistence, plankton, predator-prey, stability, temperature, type II, type III, warming