Food web modelling exercise

In this modelling part you will work with computer simulations in R, using food web models of different complexities. The aim of this part is to learn how food web structure (homogeneity or heterogeneity within trophic levels) can influence food web dynamics. You will also learn how to construct population models from graphical arrangements. By altering the formulation of food web structure in your model, you will test how heterogeneities in food webs can influence bottom-up and top-down forces. The exercise is based on the work by Peter Abrams (1993) who used 37 different food web constructions at two and three levels to show that food web structure (heterogeneity) influence the strength of bottom-up and top-down effects. You will run simulations in a few of these models

B**efore you start the modelling exercises you need to read the Abrams (1993) paper**. Focus especially on the assumptions of the models and the predictions they make.

Population model assumptions
Nutrient additions into the environment can fuel the food web and lead to that, the top-level increases and levels that are an even number of levels below the top (the so called OFAN prediction based on Oksanen, Fretwell, Arruda and Niemala 1981). The abundances of other levels are in this case unchanged. This happens if trophic levels are homogeneous. However, if trophic levels are heterogeneous (something that occurs if prey at the same trophic level differ in invulnerability to predation, interference, mutualistic interactions etc), the dynamics of the species will differ from the OFAN prediction.

You will model top-down and bottom-up food web interactions using a set of Lotka-Volterra type of models with two or three trophic levels with one or two species per level (using up to 4 species). Use the rather simplistic assumptions of Abrams on page 353 (1-4) when you construct your models. In short they are as follows:

1) All consumers have linear functional response meaning that the consumption rate of any prey type by a particular predator individual is directly proportional to the population density of the prey.
2) The per capita growth rate of a consumer is an increasing function of the sum of each prey type.
3) Per capita population growth rates are determined entirely by food intake and predation rate per individual (e.g. no competition or mutualism is involved)
4) Consumers may not feed on several trophic levels which means no omnivory.

In addition to these assumptions it is necessary to assume a specific form for the resource growth equation which is here assumed to be logistic. ie. $\frac{dR}{dt} = rR(1 - \frac{R}{k})$

Preparations before running models
You will do the modelling work in the program R. In Studium you will find an R-script for the Lotka-Volterra consumer-resource model. This is a basic two species model that also describes your first modelling task. You can use this model to build more complex models up to 4 species according to the different food web arrangements in your different tasks. Here is the basic consumer-resource model provided in the R script:

$$\frac{dR}{dt} = rR(1 - \frac{R}{k}) - aRC$$

$$\frac{dC}{dt} = eaRC - dC$$

Where r = intrinsic growth rate of resource,
R = population of resource,
k = carrying capacity of resource,
a = attack rate of consumer on resource,
C = population of consumer,
e = efficacy of take-up from resource to consumer,
d = intrinsic death rate of consumer

Tasks

A) Construct the model for the different food webs (**1 and 3**) on page 355 and test the "OFAN" prediction that the bottom level remains constant and the top-level increases when you increase productivity. Start by using the default parameter values given in "models with reasonable parameter values". Write down the equilibrium densities of the different populations after each run, in order to compare the population responses to high and low productivity (the value of carrying capacity, K). For multiple outcomes you can try to vary *a*.

1) Describe the dynamics in models 1 and 3
2) What happens to the equilibrium populations in these models when you increase productivity. Do the dynamics support the OFAN prediction?
3) Summarize your conclusions about the dynamics and try to describe what happens biologically.

B) Three trophic level food webs can be viewed as extensions of two trophic level webs. The question here is whether heterogeneities at different trophic levels can lead to differences in the effect at the top level when changing productivity at the bottom of the food web. Construct food web models using the same type of formulation and assumptions as in task A. Model the following food web configurations with three trophic levels described in Fig. 2 (Abrams 1993): **1, 17, 21**.

1) Describe the dynamics for models 1, 17 and 21.
2) What happens to the equilibrium populations in these models when you increase productivity. Do the dynamics support the OFAN prediction?
3) Summarize your conclusions about the dynamics and try to describe what happens biologically.

Make sure to document your code and answers to the questions in parallel when you work with the exercise. R Markdown allows you to do this efficiently https://rmarkdown.rstudio.com/lesson-1.html. Once you have finished all tasks you upload your R Markdown HTML file in Studium.

References computer exercise

Abrams, P. A. Effects of increased productivity on the abundance of trophic levels. Am. Nat. 141: 351-371.

Peter and Ellinor November 2022