

Phys. sp. #20 f-24,5

**INTERNATIONALE VEREINIGUNG
FÜR THEORETISCHE UND ANGEWANDTE LIMNOLOGIE**

**INTERNATIONAL ASSOCIATION
OF THEORETICAL AND APPLIED LIMNOLOGY**

**ASSOCIATION INTERNATIONALE
DE LIMNOLOGIE THEORIQUE ET APPLIQUEE**

Verhandlungen · Proceedings · Travaux

Congress in Munich 1989

Volume 24 · Part 5

Edited for the Association by V. Sládeček and A. Sládečková

World List Abbreviation: *Verh. int. Ver. Limnol.*

DIN 1502 Abkürzung: *Verh. Internat. Verein. Limnol.*



Stuttgart 1991

E. Schweizerbart'sche Verlagsbuchhandlung

(Nägele u. Obermiller)

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The impact of cannibalism on the population dynamics of cyclopoid copepods

Frank van den Bosch and Wilfried Gabriel

Introduction

Predation is one of the key factors in the dynamics of zooplankton communities (KERFOOT 1980). Therefore, it is important to improve the knowledge on the population dynamics of predacious species. Intraspecific predation (cannibalism) may strongly determine the demography of a population and thereby influence the whole community structure. It has been supposed that cannibalism, which is a widespread phenomenon (POLIS 1981), can be advantageous in cyclopoids (GABRIEL & LAMPERT 1985), especially to overcome periods of food limitations (GABRIEL 1985, VAN DEN BOSCH et al. 1988). In this paper we further explore the influence of cannibalism on the population dynamics of cyclopoids.

Method and model description

Modelling methodology

Physiology and behaviour of copepods change drastically during development. Therefore, a realistic model has to treat the various life stages separately. Building a multi-compartment model with ordinary differential equations is an insufficient approach since information on age structure within each compartment is lost. The stage-structured population modelling methodology overcomes this problem (NISBET & GURNEY 1986, and references therein).

The model

Here we give a short verbal description only. Model equations will be published elsewhere and are available on request.

Prey population: The prey population grows logistically in the absence of predators. Predation causes a certain mortality rate.

Predator demography: Here we keep the environment constant and assume that there is no food shortage for the herbivorous stages. We subdivide the cyclops population into six stages: eggs, nauplii, copepodite I and II, copepodite III and IV, copepodite V, and the adults. The mathematical treatment of individuals in each stage can be visualized as particles moving on a conveyer belt (except the adults). We discuss the copepodite I/II stage as an example. An individual maturing out off the nauplii

stage, i.e. recruiting into the CI/II stage, is placed on the left hand side of the conveyer belt. The conveyer belt moves the individuals to the right. This movement represents aging. During this aging individuals can die. Besides cannibalism as death factor, we assume a stage dependent but constant mortality rate. Individuals which are alive at the end of the conveyer belt fall onto the next conveyer belt, i.e. they mature out off the CI/II stage. The length of the conveyer belt represents the stage duration.

Predation and cannibalism: Adults and copepodite V are predators and cannibalize nauplii and copepodites of stage I/II. Predation and cannibalism have HOLLING type II functional responses (multi-prey-type functional responses, MURDOCH & OATEN 1975).

Predator reproduction: Depending on its biomass, each prey or conspecific individual eaten supplies the adult a certain amount of energy which is converted into offspring.

Calibration of the model

The model was calibrated to describe *Cyclops abyssorum*, a highly predacious and cannibalistic species. Stage durations corresponding to 12 °C were obtained from the literature. Parameters of the functional responses, biomass of various stages and of prey items and the conversion efficiency of food eaten into offspring are calculated from laboratory measurements (VAN DEN BOSCH & SANTER in prep.). *Daphnia hyalina* has been used as a representative prey species. Since death rates and carrying capacity of prey are unknown we performed runs with several combinations of values for these parameters.

Results and discussion

To study the consequences of cannibalism on population dynamics we performed a series of runs for various degrees of cannibalistic activity. To this end we multiply the experimentally determined attack rates of the predators on conspecifics with a factor C which can take values between zero and one. Zero means no cannibalism, one means the cannibalistic activity as measured in the lab, other values represents a reduced degree of cannibalism.

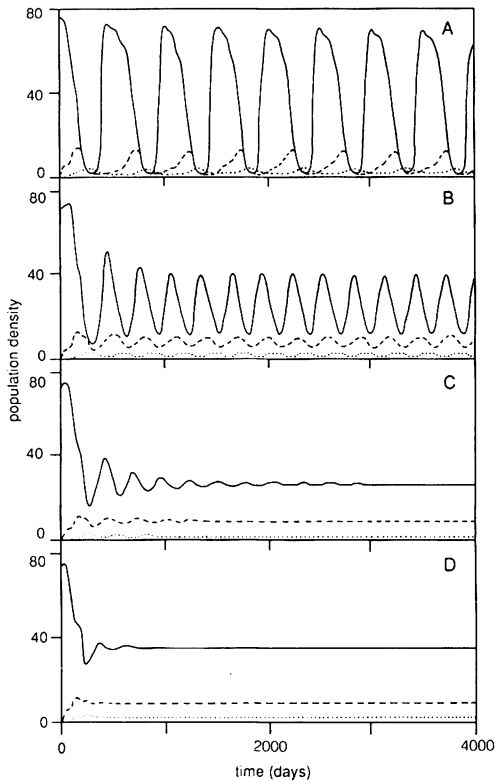


Fig. 1. Time course of the prey and predator population densities for various degrees of cannibalistic activity of the predator. Continuous line: Prey. Dashed line: Predator nauplii. Dotted line: Predator adults. A: no cannibalistic activity of the predator ($C = 0$). B: attack rates of the predator on conspecifics is 0.4 times the value measured in the lab. ($C = 0.4$). C: attack rates 0.6 times the measured values ($C = 0.6$). D: attack rates equal to the measured ones ($C = 1$).

Fig. 1 shows a characteristic series of runs. Without cannibalism ($C = 0$) the model gives the well known predator-prey oscillations. The prey and all stages of the predator show stable cyclic changes with an approximate period of 500 days. The predator lags behind the prey by approximately one quarter of a period. When cannibalistic activity is put to the values measured in the laboratory ($C = 1$) the population rapidly converges to a stable equilibrium, i.e. no changes in density or composition of the population. For degrees of cannibalism other than zero or one there can be two kinds of behaviour: (i) The system converges to a stable equilibrium, but this takes a

longer time compared to full cannibalistic activity. (ii) The system shows cyclic fluctuations with a smaller amplitude than in the non-cannibalistic case.

Fig. 2 summarizes a large number of runs with the same parameter values as in Fig. 1. Leaving out the first parts of the runs where the populations are not yet at their "final behaviour", the maximum and minimum population density of prey, nauplii and adults are plotted for each run dependent on the degree of cannibalism (C). The figure shows the gradual change from predator-prey oscillations with large amplitudes to stable equilibria as the degree of cannibalism increases.

The model presented here is, as any model, an oversimplification of reality. It, however, enables

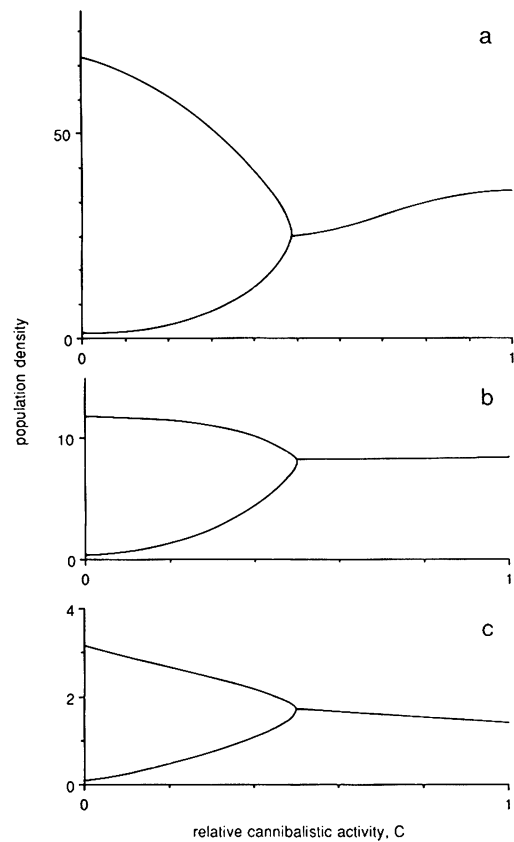


Fig. 2. Maximum and minimum population densities of prey (a), predator nauplii (b), and predator adults (c), (for the "final behaviour") as a function of C (cannibalism attack rates in the simulation = C times cannibalism attack rates measured in the lab.).

us to study possible population dynamical consequences of cannibalism. In the laboratory or in the field, such investigations would be extremely difficult if not impossible. Further research on this is needed before we can generalize our findings. In the light of the present results we can pose the hypothesis at least in the case of *Cyclops abyssorum*: Cannibalism is a stabilizing mechanism capable of suppressing or even completely eliminating predator-prey oscillations.

Acknowledgements

W. G. is grateful to the "Nederlandse Organisatie voor Wetenschappelijk Onderzoek" (N. W. O.) and F. vd. B. to the Max-Planck-Gesellschaft for financial support.

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