CANNIBALISM IN AN AGE-STRUCTURED PREDATOR–PREY SYSTEM

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Recently, Kohlmeier and Ebenhöh showed that cannibalism can stabilize population cycles in a Lotka–Volterra type predator–prey model. Population cycles in their model are due to the interaction between logistic population growth of the prey and a hyperbolic functional response. In this paper, we consider a predator–prey system where cyclic population fluctuations are due to the age structure in the predator species. It is shown that cannibalism is also a stabilizing mechanism when population oscillations are due to this age structure. We conclude that in predator–prey systems, cannibalism by predators can stabilize both externally generated (consumer-resource) as well as internally generated (age-structure) fluctuations.

1. Introduction. Cannibalism is a widespread phenomenon among a variety of taxa (Fox, 1975; Polis, 1981; Elgar and Crespi, 1992). Cannibalism has effects at both the individual and the population level. At the individual level, a cannibal gains food, whereas from the point of view of the victim, cannibalism increases the death rate. The effect on death rate can be substantial. Van den Bosch and Santer (1993), for example, calculated the probability that a juvenile of the predatory copepod Cyclops abyssorum falls victim to cannibalism before reaching the adult stage. They found annual averages between 6% and 35% with peak values of up to 80%. Polis (1981) lists a number of other species for which comparable numbers have been calculated.
At the population level, cannibalism has the potential of regulating population size. Polis (1981) lists 40 experimental and field studies reporting cannibalism as a density-dependent regulator in beetles, tribolium, copepods, scorpions, several fish species and even crows. Another well-studied effect of cannibalism is the so-called “lifeboat mechanism.” Populations of cannibalistic predators can survive periods of food shortage, whereas non-cannibalistic populations would go extinct (Gabriel, 1985; van den Bosch et al., 1988; Cushing, 1991, 1992).

Cyclic population fluctuations have been intensively studied in various ecological systems during the last decades. Stabilizing and destabilizing mechanisms are identified for predator–prey systems, parasitoid–host interactions and competitive interactions. Does cannibalism promote or oppose population cycles? Depending on the model study considered, one comes to different conclusions. Diekmann et al. (1986) found that egg cannibalism can lead to population oscillations. Hastings (1987) shows that cannibalism is destabilizing in his model for Tribolium dynamics. Desharnais and Liu (1987), however, showed in a Tribolium model that cannibalism is stabilizing. Cushing (1991) found both a stabilizing and a destabilizing effect of cannibalism depending on parameter values. In a further paper, Cushing (1992) derives a size-structured model for a cannibalistic population. He concludes that population oscillations are more due to age or size structure than to cannibalism. From these studies, we can conclude that it depends on the details of the biological system considered whether cannibalism is stabilizing or destabilizing. There is a need for a systematic investigation of cannibalism in various biological systems.

Cannibals are usually predacious species. Is cannibalism a stabilizing or a destabilizing factor in predator–prey interactions? Recently, Kohlmeier and Ebenhöh (1995) started the systematic investigation of predator–prey systems with cannibalistic predators. They used a Lotka–Volterra type predator–prey model with logistic prey growth and a Holling type II functional response and added a cannibalism term. Their model reads

\[
\frac{dz(t)}{dt} = rz(t) \left(1 - \frac{z(t)}{K}\right) - \frac{\alpha z(t)P(t)}{1 + \alpha h_1 z(t) + \theta h_2 P(t)}
\]

\[
\frac{dP(t)}{dt} = \gamma \frac{\alpha z(t)P(t)}{1 + \alpha h_1 z(t) + \theta h_2 P(t)} - \omega P(t) - \frac{\theta P(t)^2}{1 + \alpha h_1 z(t) + \theta h_2 P(t)}
\]

(1)

where \(z(t)\) and \(P(t)\) are the density of prey and predator, respectively; \(r\) and \(K\) are the growth rate and carrying capacity of the prey population; \(\alpha\) and \(\theta\) are the attack rates on prey and conspecifics; \(h_1\) and \(h_2\) are the