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Timing of Reproduction in Consumer-Resource Interactions
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Summary

Timing of reproduction in consumer-resource interactions

This thesis presents the results of the analysis of consumer-resource models with seasonal reproduction of the consumer. The population dynamics were studied in Chapters 2, 3 and 4 while the evolutionary dynamics were studied in Chapter 5. Furthermore, the seasonality of resource growth was also formulated and its effect was investigated in Chapters 4 and 5.

In Chapter 2 a stage-structured consumer-resource biomass model with seasonal reproduction and an ontogenetic niche shift was formulated, and the fixed-point dynamics were studied. We investigated how the resource productivities and the extent of the niche shift affect the average consumer biomass. The results showed that the resource productivities, together with the extent of the niche shift, determine the resource availabilities for the two consumer stages. We found that the model can be governed by a development-controlled state when juveniles are more limited by their resource (e.g., when the resource availability for the adult stage is higher than that for the juvenile stage), or by a reproduction-controlled state when adults are more limited. Between these two states there exists a parameter region in which these two states coexist, which can be referred to as alternative stable states or bistability. We also studied the model variants with different resource dynamics and a different functional response, all the results showed the robustness of the existence of the energetic asymmetry between the two stages. It was revealed that the seasonal reproduction of the consumer does not qualitatively affect the energetic asymmetry but only results in some quantitative differences. In particular, the seasonal reproduction of adults can more or less relaxes the competition at the juvenile stage, leading to a smaller development-controlled region.

In Chapter 3 a similar stage-structured consumer-resource biomass model with one shared resource was formulated. Unlike the model studied in Chapter 2, in this chapter the energetic asymmetry was formulated by the mass-specific intake ratio of adults compared to juveniles. We investigated the effect of the increasing background mortality rate of the consumer. It was found that when the mortality rate increases, biomass overcompensation in one specific stage may occur because the bottleneck in the other stage can be more or less relaxed. More importantly, the increasing mortality rate can result in an Allee effect and collapse of the consumer. We reported a new mechanism for the Allee effect to occur: the time delay between the maturation of juveniles and the reproduction of adults. This Allee effect was not observed in the continuous-time models in the literature, and can only occur when adults have a sufficiently high intake rate, for the reason that a higher intake rate of adults strengthens the seasonality in the model. As a consequence, a higher intake rate of adults can increase the possibility of the occurrence of an Allee effect and population collapse.

In Chapter 4 we considered the effect of pulsed resource dynamics and investigated the effect of the parameters on the average consumer density. In particular, the effect of the resource turn-over rate and the timing of resource pulse was studied. We showed that the consumer can benefit from a substantial mismatch between the reproduction of the consumer and the input of the resource. The effect of the resource turn-over rate is influenced by the type of the resource dynamics and the type of the consumer mortality rate. As the most distinguishing result, in the case of pulsed resource dynamics and a resource-dependent mortality rate, the increasing turn-over rate may lead to extinction of the consumer, for the reason that it increases the average mortality rate of the consumer. We also compared the primary model to the model variants with continuous resource dynamics and/or constant mortality rate, and presented the results of the analysis. All the results revealed the influence of the pulsed resource dynamics and the resource-dependent mortality rate, and led to the consideration that how consumers time their reproduction to adapt to the phenology of their resource is crucial to their persistence.

In Chapter 5 the evolution of the reproduction periods of a stage-structured consumer population in seasonal environments was studied. We formulated the environmental changes using a periodic growth rate of the resource, which is controlled by two main parameters: the fluctuation amplitude and the width of the peak. The results showed that two qualitative different reproduction strategies may evolve: income breeding strategies and capital breeding strategies. The results also showed that the evolution depends on the resource growth rate as well as the energetic asymmetry between the two consumer stages. When adults have a higher intake rate on the resource compared to juveniles they will never starve, in such circumstances in significantly fluctuating environments capital breeding strategies will evolve while if the fluctuations are small income breeding strategies will evolve. When compared to juveniles the intake rate of adults is low, they can starve at some time of the year. In strongly seasonal environments capital breeding will only evolve when the intake rate of adults is not too low. Otherwise, adults have a distinct starvation period within the year and they will attempt to reproduce when they are not starving, income breeding strategies will thus evolve. We also showed that there exists bistability, when capital breeding strategies are not sufficiently advantageous, in which both two types of strategy have the potential to evolve.

Overall, this thesis reported theoretical models on the seasonality in consumer-resource interactions. Several topics are studied and discussed, including unstructured and structured models, population and evolutionary dynamics, continuous and pulsed/seasonal resource dynamics, energetic asymmetry between different consumer stages, ontogenetic niche shifts, and so on. The approaches presented in the chapters provide new methods on the formulation and analysis of seasonality and phenology in consumer-resource interactions, and can be further used in studying the dynamics of more complex ecological systems.