Spatial and temporal dynamics of structured-populations: Theoretical analyses

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By

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Abstract

Structured populations are populations that are divided into discrete groups that interact differently with their environment. Criteria by which the population is divided and the interactions between these groups are dependent on the biology of the studied species. In the current study we examined how population structures affect the temporal and spatial dynamics of populations and communities. We paid a special attention to contrast the dynamics of a structured population to that of an identical unstructured one.

The study is concentrated on three aspects of structured population dynamics: (1) the effect of predation on different age stages of the prey on the temporal dynamic of a two predator-one prey system; (2) the effect of individualistic assessment of patch quality on individual spatial distribution in a patchy habitat; and (3) the effect of non-uniform spatial distribution of competitors in a homogeneous habitat on their temporal dynamics. In my study I used probabilistic models and non-linear dynamics. All numerical simulations were performed in MATLAB.

In (1) I modeled a community with age-structured prey and two predator species. Each predator may attack two stages of the prey, juveniles and adults, at variable proportion. These predators may therefore function in a complementary or redundant way. The model consists of four coupled non-linear differential equations with a special control parameter that determines the proportion of the stages being attacked by the predators.

Analysis of the model shows that a community where each predator concentrates on a specific prey stage is more stable than a community where each predator consumes both prey stages. Therefore, predator functionality (i.e., being redundant or complementary) has a significant effect on the stability of the modeled community. Since age-specific predation promotes the coexistence of both predators, such communities are expected to be more specious.

In many cases, species inhabit habitats in which resource patches are significantly larger than the individual foraging range. Examples include insects in large fields and water fowls scattered over a big lake. In (2), I constructed a probabilistic model (that involved nonlinear dynamics) in order to predict animal

distribution among patches when the patch size is significantly larger than the foraging range of individuals. The model assumes a habitat which consists of two patch types of different quality. Individuals assess the patches according to the gain in their immediate surroundings, the competition neighborhood (CN), that may be small compared to the patch being sampled. The gain derived from a CN depends on the number of individuals occupying it and other patch-dependent parameters (such as resource quantity and availability). When organisms are non-uniformly distributed within patches, the number of competitors varied among individual CN's and so does the CN gains. Therefore, individuals inhabiting the same patch may evaluate it differently. The modeled population is structured because it is divided into groups based on the perceived quality of the patch. In general, individuals move randomly in the habitat. If however they cross the border between two patch types, they choose to settle in the patch with the higher evaluated gain (according to the CNs they have sampled).

My analysis shows that under the model conditions, all individuals will converge to a unique spatial distribution regardless of their initial distribution pattern. This distribution is usually not an Ideal Free Distribution (IDF) because different individuals may experience different gains. We have quantified the deviation from the IDF for two widely used gain functions. Those deviations depend, in a relative complicated way, on CN dimensions, gain function parameters, and total population size

In (3) I constructed an Individual Based Model (IBM) in order to explore the temporal dynamics of a competitor population that is non-uniformly distributed in a homogeneous habitat. In the model, I assumed that each individual is affected only by interactions with conspesifics in its vicinity, i.e., in its CN. Since the distribution is not uniform, each individual experiences different population density in its CN and reproduces accordingly. The temporal dynamics of the population is therefore determined by summing up the reproduction rates of all individuals. The modeled population is spatially structured: different groups in the population exhibit different reproduction rates according to their location in relation to conspecifics. The model parameters were chosen so that at steady-state, the population would exhibit periodic oscillations.

Model simulations indicate that a decrease in CN dimensions lowers the coefficient of variance in population size, and the total population size is affected by both, animal mobility and CN dimensions. My study indicates that competitor populations, whose interaction range is significantly smaller than their habitat dimensions, fluctuate less and therefore are more likely to persist. These results could be applied for the conservation of such populations.

My study presented two types of population structuring; in (1) the population is divided according to age and in (2) and (3) it is divided according to the competitor density within individual vicinity. These types of structures have been studied previously. Yet, my work presented novel effects of theses structures on the spatial and the temporal dynamics of populations and communities.