Species interactions and population growth

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Interspecific interactions:

Community-level interactions are made up of the combined interactions between species within the biological community where the species coexist. The effects of one species upon another that derive from these interactions may take one of three forms: positive (+), negative (–), and neutral (0). Hence, interactions between any two species in any given biological community can take any of six forms:

1. Mutualism (+, +), in which both species benefit from the interaction.
2. Exploitation (+, –), in which one species benefits at the expense of the other.
3. Commensalism (+, 0), in which one species benefits from the interaction while the other species neither benefits nor suffers.
4. Interspecific competition (–, –), in which both species incur a cost of the interaction between them.
5. Amensalism (–, 0), in which one species suffers while the other incurs no measurable cost of the interaction.
6. Neutrality (0, 0), in which both species neither benefit nor suffer from the interaction.

Lotka-Volterra equations:

The effects of species interactions on the population dynamics of the species involved can be predicted by a pair of linked equations that were developed independently during the 1920s by American mathematician and physical scientist Alfred J. Lotka and Italian physicist Vito Volterra. Today the Lotka-Volterra equations are often used to assess the potential benefits or demise of one species involved in competition with another species:

$dN_1/dt = r_1N_1(1 – N_1/K_1 – \alpha_{1,2}N_2/K_2)$………………...1

$dN_2/dt = r_2N_2(1 – N_2/K_2 – \alpha_{2,1}N_1/K_1)$………………...2

Here r = rate of increase, N = population size, and K = carrying capacity of any given species.

In the first equation, the change in population size of species 1 over a specific period of time (dN_1/dt) is determined by its own population dynamics in the absence of species 2 ($r_1N_1[1 – N_1/K_1]$) as well as by its interaction with species 2 ($\alpha_{1,2}N_2/K_2$). As the formula implies, the effect of species 2 on species 1 ($\alpha_{1,2}$) in turn is determined by the population size and carrying capacity of species 2 (N_2 and K_2).

The possible outcomes of interactions between two species are predicted on the basis of the relative strengths of self-regulation versus the species interaction term. For instance, species 2 will drive species 1 to local extinction if the term $\alpha_{1,2}N_2/K_2$ exceeds the term $r_1N_1(1 - N_1/K_1)$—though the term $\alpha_{1,2}N_2/K_2$ will exert a decreasing influence over the growth rate of species 1 as

$\alpha_{1,2}N_2/K_2$ diminishes. Consequently, the first equation represents the amount by which the growth rate of species 1 over a specific time period will be reduced by its interaction with species 2. In the second equation, the obverse applies to the dynamics of species 2.

In the case of interspecific competition, if the effects of both species on each other are approximately equivalent with respect to the strength of self-regulation in each species, the populations of both species may stabilize; however, one species may gradually exclude the other over time. The competitive exclusion scenario is dependent on the initial population size of each species. For instance, when the interspecific effects of each species upon the abundance of its competitor are approximately equal, the species with the higher initial abundance is likely to drive the species with a lower initial abundance to exclusion.

The basic equations given above, describing the dynamics deriving from an interaction between two competitors, have undergone several modifications. Chief among these modifications is the development of a subset of Lotka-Volterra equations that calculate the effects of interacting predator and prey populations. In their simplest forms, these modified equations bear a strong resemblance to the equations above, which are used to assess competition between two species:

$$dN_{prey}/dt = r_{prey} \times N_{prey}(1 - N_{prey}/K_{prey} - \alpha_{prey,\, pred} \times N_{pred}/K_{pred})$$

$$dN_{pred}/dt = r_{pred} \times N_{pred}(1 - N_{pred}/K_{pred} + \alpha_{pred,\, prey} \times N_{prey}/K_{prey})$$

Here the terms N_{pred} and K_{pred} denote the size of the predator population and its carrying capacity. Similarly, the population size and carrying capacity of the prey species are denoted by the terms N_{prey} and K_{prey}, respectively. The coefficient $\alpha_{prey, pred}$ represents the reduction in the growth rate of prey species due to its interaction with the predator, whereas $\alpha_{pred, prey}$ represents the increase in growth rate of the predator population due to its interaction with prey population.

Several additional modifications to the Lotka-Volterra equations are possible, many of which have focused on the incorporation of influences of spatial refugia (predator-free areas) from predation on prey dynamics.

REF:

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