Population dynamics in an intermittent refuge

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Population dynamics is constrained by the environment, which needs to obey certain conditions to support population growth. We consider a standard model for the evolution of a single species population density, that includes reproduction, competition for resources and spatial spreading, while subject to an external harmful effect. The habitat is spatially heterogeneous (see Fig. 1), there existing a refuge where the population can be protected [1, 2, 3]. Temporal variability is introduced by the intermittent character of the refuge.

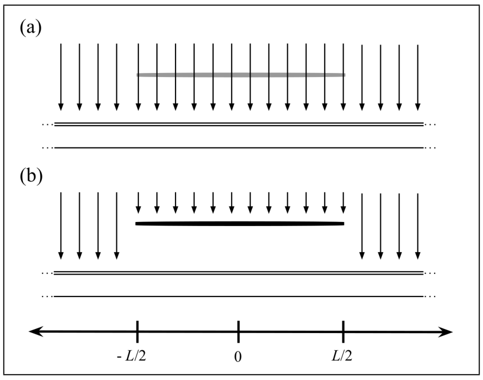

Figure 1: Pictorial representation of a onedimensional habitat subject to an external harmful effect (downwards arrows) with a refuge (thick segment) of size L in the inactive (a) and active (b) states. In the active state, the refuge is able to block the harmful effect.

Explicitly, we assume that the temporal evolution population density distribution $u(x,t)$ is given by

$$\partial_t u(x,t) = D\partial_{xx}u(x,t) + f(u) + \psi(x,t)u(x,t)\,, \quad (1)$$

with

$$\psi(x,t) = -A\left(1 - \Theta(L/2 - |x|)\varphi(t)\right)\,, \quad (2)$$

with $A > a$. The parameter D is the diffusion coefficient, $f(u) = au(x,t)\left[1 - \frac{u(x,t)}{K}\right]$, with intrinsic growth rate a and carrying capacity K. The temporal behavior is given by φ which is assumed to be periodic or random. The parameter λ controls the fraction of time that the refuge is inactive and τ is the environment time scale.

Depending on the refuge size L, the population can be driven to extinction ($L < L_c$) or survival ($L > L_c$). The value of the critical size L_c depend on the problem spatiotemporal scales. We obtain approximate expressions for the critical size L_c for the slow ($\tau \ll \tau_S$) and fast environment ($\tau \gg \tau_S$), where $\tau_S \sim 1/a$ is the system time scale. Numerical simulation are also used to complement our results, investigating the conservation of the population for different refuge temporal behavior.

The results can applied to a wide range of situations, from a lab setting where bacteria can be protected by a blinking mask from ultraviolet radiation [2], to large scale ecosystems, like a marine reserve [3] where there can be seasonal fishing prohibitions.

Our results may be useful to provide insights to guide management of ecological reserves when the population is sensitive to environment temporal variability [3].

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