Single species dynamics under climate change

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Abstract

We propose a general mathematical model describing the growth and dispersal of a single species living in a 1-D spatially discrete array of habitat patches affected by a sustained and directional change in climate. Our model accounts for two important characteristics of the climate change phenomenon: (1) Scale dependency: different species may perceive the change in the environment as occurring at different rates because they perceive the environment at different scales, and (2) measure dependency: different species measure the environment differently in the sense that they may be sensible to or cue in on different aspects of it (e.g., maximum temperature, minimum temperature, accumulated temperature) which is associated with their physiological, ecological, and life history attributes, which renders some characteristics of the environment more biologically relevant than others. We show that the deterioration in the quality of habitable patches as a consequence of climate change drives the species to extinction when dispersal is not possible; otherwise, we proof and provide a numerical example that, depending on the velocity of climate change, the scale at which a species measures it, and the particular attribute of the environment that is more biologically relevant to the species under analysis, there is always a migration strategy that allows the persistence of the species such that it tracks its niche conditions through space, thus shifting its geographic range. Our mathematical analysis provides a general framework to analyze species' responses to climate change as a relational property of a given species in interaction with a change in climate. In particular, we can analyze the persistence of species by taking into account the ways in which they measure and filter the environment. Indeed, one of our main conclusions is that there is not a single climate change but many, as it depends on the interaction between a particular species and climate. Thus, the problem is more complex than assumed by analytically tractable models of species responses to climate change..

Keywords

Climate change, Species dynamics, Temporal scale dependency, Allee effect threshold, Species' fundamental niche, Migration strategies, Threshold migration rate.