Modeling Large Scale Invasion of New Species under Temperature Change by Reaction-diffusion Equations

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Abstract: The spatial dynamics of range expansion is studied in dependence of temperature. The main elements population dynamics, competition and dispersal are combined in a coherent approach based on a system of coupled partial differential equations of the reaction diffusion type. The nonlinear reaction terms comprise population dynamic models with temperature dependent reproduction rates subject to an Allee effect and mutual competition. The effect of temperature on traveling wave solutions is investigated for a one dimensional model version. One main result is the importance of the Allee effect (dependence of fertility rates on species density) for the crossing of regions with unsuitable habitats. The non linearities of the interaction terms give rise to a richness of spatio-temporal dynamic patterns such as multiple steady states and bifurcations. In two dimensions, the resulting non-linear initial boundary value problems are solved over geometries of heterogeneous landscapes. Geo referenced model parameters such as mean temperature and elevation and landscape covers are imported from a geographical information system into the finite element tool COMSOL Multiphysics based on the Petrov-Galerkin scheme. The model is applied to the range expansion of species at the scale of Central Europe. The results support the assumption that range expansion can be sufficiently simulated as a nonlinear threshold process depending on ambient temperature and species-specific temperature response functions. Once a threshold is surpassed, dispersal occurs in form of a travelling wave. The speed of the wave front, i.e. the rate of spread of an invasion, is dependent on ambient temperature, species-specific optimum temperature, strength of the Allee effect and landscape structures. Simulations of future warming show that increasing temperature may alter the distribution range of a species drastically.

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