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Pushing the boundaries: the existence of solutions for a free boundary problem modeling the spread of ecosystem engineers

The overwhelming majority of models for the spread of an invasive species into a new environment are based on Fisher's reaction-diffusion equation. This approach assumes that habitat quality is independent of the population. Ecosystem engineers are species that modify their environment to make it (more) suitable for them. Beavers are a well-known engineering species. A potentially more appropriate modeling approach is to adapt the well-known Stefan problem of melting ice. Ahead of the front, the habitat is unsuitable for the species (the ice); behind the front, the habitat is suitable (the open water). The engineering action of the population moves the boundary ahead (the melting). This modeling approach leads to a time-dependent free boundary problem where the boundary corresponds to the edge of the population front.

We present a novel model for the spread of ecosystem engineers as a free boundary problem. We derive the semilinear parabolic equation from an individual random walk model. The Stefan condition for the moving boundary is replaced by a biologically derived two-sided condition that models the movement behavior of individuals at the boundary as well as the process by which the population moves the boundary to expand their territory.

We prove the local existence of solutions for the model. We assign a convex functional to this problem so that the evolution system governed by this convex potential is exactly the system of evolution equations describing the above model. We shall then apply variational and fixed-point methods to deal with this free boundary problem.