Avenues of Spatially Explicit Population Dynamics Modeling — A *par excellence* Example for Mathematical Heterogeneity in Ecological Models?

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Abstract: This contribution discusses different approaches to spatially explicit modeling of population dynamics of the intrusion of non-endemic species into patched habitats. Different modeling approaches such as cellular automata, partial differential equations and hybrid Petri nets are summarized. An application of a meta–population model for the Galapagos archipelago is described using a partial differential equation and a Petri net model. A detailed comparison of both models in terms of simulation results and methodology shows how different building blocks of ecological models can be. And the question is raised, how far the integration of models is at all possible and should be aimed at. Results of the investigation give a detailed insight into the problem of scaling ecological models and the core question of what processes should be considered in which scale in terms of space, time or complexity.

Keywords: Population Dynamic Modeling, Meta-Population, hybrid Petri Nets, PDE, Habitat Patches

1 INTRODUCTION

1.1 Mathematical Heterogeneity in Ecological Models

Modeling ecological processes often leads to simulation models which may by characterized as mathematically heterogeneous [Seppelt 2001]. This means, simulation models consist of different mathematical structures such as ordinary and partial differential equations, stochastic elements as well as matrix equations.

One main reason for this is that ecological models are a product of interdisciplinary research. Models comprise approaches from biology, chemistry, physics, ecology etc. Besides, physically based models – so called white box models – are not available for every scale in terms of space, time or complexity. Ecological models comprise physical models as well as statistical and phenomenological models – black- and gray-box models. Finally, different modeling environments or software-tools are used for model development.

1.2 Spatially Explicit Population Dynamic Models

Spatially explicit population models encompass the processes of

- spatial spread of individuals by migration or distribution by wind
- population dynamics, and
- depend on a spatially explicit habitat suitability model.

Different methodologies were presented in recent literature. Cellular automation models seem to be the most common solution. This approach represents the landscape by a regular mesh of equally sized grids. Information exchange (migration, habitat suitability) is possible between two neighbored cells. A population model is attributed to each cell and parameterized by associated habitat parameters. This model of population dynamics may be of any kind (Matrix, Lesli Model), c.f. for example [Schröder & Söndgerath, 2002, Richter et al. 2002].
Other approaches vary in mathematical as well as spatial structure. Obviously, all models depend on the specific problem to solve. However, two distinct approaches can be identified when looking at the representation of the landscape: a continuous and a discrete parameterization of the habitat properties in space.

1.3 Aim and Scope

For detailed analysis two entirely different modeling approaches are chosen here to model spatially explicit population dynamics:

1. Based on a modified McKendrick–Foerster–equation, a partial differential equation (pde) covering the physical processes of migration, growth and wind-spread solved by a dynamic finite element solver, and