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EMPHASIZING NEW IDEAS TO STIMULATE RESEARCH IN ECOLOGY

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Beyond description: the active and effective way to infer processes from spatial patterns

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Abstract. The ecological processes that create spatial patterns have been examined by direct measurement and through measurement of patterns resulting from experimental manipulations. But in many situations, creating experiments and direct measurement of spatial processes can be difficult or impossible. Here, we identify and define a rapidly emerging alternative approach, which we formalize as "space as a surrogate" for unmeasured processes, that is used to maximize inference about ecological processes through the analysis of spatial patterns or spatial residuals alone. This approach requires three elements to be successful: a priori hypotheses, ecological theory and/or knowledge, and precise spatial analysis. We offer new insights into a long-standing debate about process–pattern links in ecology and highlight six recent studies that have successfully examined spatial patterns to understand a diverse array of processes: competition in forest-stand dynamics, dispersal of freshwater fish, movement of American marten, invasion mechanisms of exotic trees, dynamics of natural disturbances, and tropical-plant diversity. Key benefits of using space as a surrogate can be found where experimental manipulation or direct measurements are difficult or expensive to obtain or not possible. We note that, even where experiments can be performed, this procedure may aid in measuring the in situ importance of the processes uncovered through experiments.

Key words: *a priori inference; competition; dispersal; diversity; ecological processes; invasion; space as a surrogate; spatial pattern; spatial residuals.*

[W]e must find ways to quantify patterns of variability in space and time, to understand how patterns change with scale . . . , and to understand the causes and consequences of pattern . . . .

—Simon A. Levin (1992:1961)

Introduction

A major objective of ecological research has been quantifying and determining the underlying processes responsible for spatial patterns of ecological phenomena (Tilman and Kareiva 1997, Liebhold and Gurevitch 2002, Tuda 2007). To date, the link between spatial pattern and process has been addressed using: (1) experimentation (e.g., Fonteyn and Mahall 1981, Stoll and Prati 2001, Kikvidze et al. 2005, McIntire and Hik 2005); (2) direct parameterization of spatial models from data (e.g., Turchin 1998, Schultz and Crone 2001, Clark et al. 2004); (3) simulation of processes within a spatial domain (e.g., Pacala et al. 1996, He and Mladenoff 1999, Fall and Fall 2001, Fortin and Dale 2005, McIntire et al. 2007); and (4) through analysis of the spatial pattern itself with the goal of uncovering the process (e.g., Olden et al. 2001, Tuomisto et al. 2003, McIntire 2004, Fang 2005, Broquet et al. 2006, Fajardo and McIntire 2007). Authors that have attempted the fourth approach have often indicated difficulty when measuring the process directly or building experiments (e.g., Jolles et al. 2002, Fajardo and McIntire 2007) because they are not practical (Schurr et al. 2004, Clark 2007), prohibitively expensive, unethical, or overly time consuming, leaving them with this pattern–process approach as a sole option. The aim of this paper is to propose a framework for using space as a surrogate for uncovering ecological processes from the study and analysis of spatial patterns or spatial residuals.

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