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Challenges in Understanding the Functions of Ecological Heterogeneity

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Abstract

Ecological systems usually are heterogeneous, and this heterogeneity has important functional consequences. Nevertheless, it is not always necessary for ecologists to explicitly include this heterogeneity in their studies and models of ecological systems. Heterogeneity may be safely ignored if its grain size is much smaller than the spatial extent over which measurements are integrated or much larger than the spatial extent of the study area. Heterogeneity may be functionally unimportant if the vectors connecting patches are small or slow relative to the time span of the study or if the system is governed by processes with linear dynamics. Further, the heterogeneity expressed by some ecological systems may be amenable to analysis using simplified models. Finally, it may not be efficient to include heterogeneity in study designs or models, even if including heterogeneity would improve the study performance. Despite these considerations, ecologists will need to address heterogeneity explicitly in many cases to achieve a satisfactory understanding of ecosystem functioning, particularly for regional to global scales.

Several other general issues concerning the functional consequences of heterogeneity arose at the Tenth Cary Conference. Human-caused heterogeneity probably has different characteristics and functional consequences than heterogeneity arising from other sources and therefore needs special attention. Models of heterogeneity developed in other disciplines that deal with heterogeneous, reactive systems (e.g., economics) may have application in ecology. At least some heterogeneous ecological systems appear to evolve in predictable ways because the functional consequences of heterogeneity feed back onto the structure of the system; these feedbacks need further study.

Introduction

All models are wrong, but some are useful.
—G.E.P. Box

The subject of ecological heterogeneity encompasses a diverse collection of scientific, management, and policy issues, many of which are important to ecology and difficult to address. The diversity of issues and rapid pace of conceptual and empirical progress on ecological heterogeneity make it difficult to summarize the current state of the field, and I will not try to provide such a summary based on the Tenth Cary Conference. Instead, I will offer brief impressions of some interesting issues that arose at the conference, lay out research challenges, and, where possible, suggest directions in which answers might lie.

A Model of Heterogeneity

It may be useful to introduce a simple conceptual model of a functionally heterogeneous system to provide a context for a discussion of the issues that arose at the conference. Consider a system (shown as two-dimensional in Figure 20.1 but more often three-dimensional in ecological contexts) consisting of a series of patches (Figure 20.1A) with different functional attributes (such as denitrification rate, prey abundance, leaf area index,

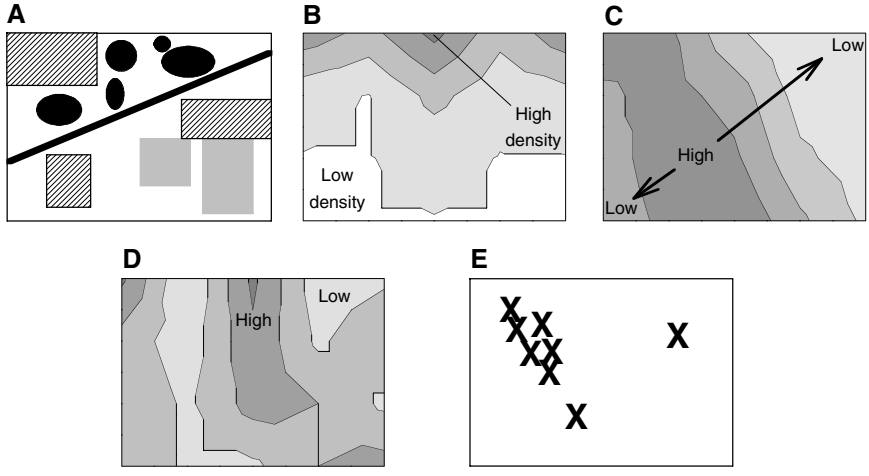

FIGURE 20.1. General model of a heterogeneous system, emphasizing five aspects of heterogeneity occurring in the same hypothetical geographical area. (A) Patch structure, (B) vector mass-density, (C) potential field, (D) resistance, (E) location of externally driven disturbances.