23
Heterogeneity and Ecosystem Function: Enhancing Ecological Understanding and Applications

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Abstract

Four themes emerging from papers presented at the Tenth Cary Conference are discussed in this synthesis. First, conditions are considered in which both landscape composition and configuration influence ecosystem function. Where there is some vector of flow (e.g., water, wind, animal) between landscape components that differ in type or rate of ecosystem processes, configuration will influence ecosystem function. The second theme is that a network perspective offers opportunities to advance both theoretical and applied analyses of landscape heterogeneity. Analyses of the interaction of human and natural networks and of networks and patches are fruitful areas for future research. A third theme is the need to reflect more fully the diversity of human activities and their history and institutions when assessing landscape heterogeneity and ecosystem function. Finally, an enhanced understanding of landscape heterogeneity and ecosystem function will improve four aspects of human interactions with nature: the framework of environmental regulations, management of land and water resources, environmental design, and ecosystem restoration. Realizing these improvements requires that we find a vocabulary to express to the public the influence of landscape heterogeneity on ecosystem function and hence the ecosystem services that society values.

Introduction

This paper provides a synthesis of the Tenth Cary conference papers and discussions from the perspective of an aquatic ecologist. I explore four themes that emerged as conference participants discussed the consequences of landscape heterogeneity on ecosystem function: (1) Both composition and configuration impact ecosystem function under certain conditions. (2) Network analysis offers opportunities to explore the impact of configuration on ecosystem function. (3) Expanding ecological horizons to include

heterogeneity of humans and their institutions into ecological analyses of landscape heterogeneity offers exciting research opportunities. (4) Application of an enhanced understanding of the consequences of spatial heterogeneity on ecosystem function could improve environmental regulations, management, design, and restoration.

Composition and Configuration

Conference participants considered the question of when and how spatial heterogeneity impacts ecosystem function. Turner and Chapin (this volume) identified a series of conditions in which heterogeneity would have an impact. These included situations where the impact was a consequence of variation in landscape composition, such as where spatial heterogeneity in process rates resulted from differences in community composition (e.g., vegetation patches differing in time since last fire). They also identified situations where both composition and configuration mattered, such as when horizontal transfers occur between patches that exhibit different processing rates.

Population ecologists have a long history of considering the impacts of spatial heterogeneity on population persistence (Fahrig and Nuttle this volume). Landscape composition is often of importance in controlling birth and death rate of populations, and hence population persistence. Landscape configuration is of importance where animals show a strong response to boundaries resulting in interpatch movement, which, combined with high probability of local extinction or use of multiple habitat types, alters birth and death rates and hence population persistence.

In her presentation at the Cary Conference, Lenore Fahrig used a flow diagram to illustrate these ideas. I have modified that figure (Figure 23.1) to consider how composition and configuration impact ecosystem function. As illustrated in the figure, ecosystem function is the net result of a number of ecosystem processes. Rates of these processes are influenced directly by landscape composition. For example, nitrogen delivery by a river to an estuary is an example of an ecosystem function resulting from processes such as leaching from soils, terrestrial and aquatic plant uptake rates, and microbial processes in soils and streams. There is an extensive literature documenting how landscape composition (e.g., proportion of land in crops *vs.* forest *vs.* urban) alters the amount of N delivered to rivers and hence its concentration (e.g., citations in Gergel et al. 2002; Turner and Rabelais 2003). The concentration of N in rivers regulates the rate of ecosystem processes such as N uptake and transformation by aquatic plants and microbes (e.g., Dodds et al. 2002). In situations where process rates vary little between landscape patches or where there is little exchange between patches, ecosystem function reflects landscape composition, and configuration is relatively unimportant (arrows on the left in Figure 23.1). But, as illustrated by arrows on