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The Role of Spatial Heterogeneity in the Management of Freshwater Resources

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Abstract

Spatial heterogeneity of ecosystem structure and function is rarely taken into consideration in the management of our planet's freshwater resources. Incorporation of spatial heterogeneity provides a new way to view freshwater resources and leads to potentially useful management strategies. In this chapter, we address the relationship between the management of freshwater resources and spatial heterogeneity by introducing landscape concepts as they apply to water management, developing a conceptual framework, describing how this relationship applies to ecosystem services provided by fresh water, and using a case study that explains the potential relevance of spatial heterogeneity to water management.

Landscape connectivity can be viewed as the overarching feature linking aquatic systems, with six types of landscape connections: two types of longitudinal (upstream-downstream and hydrogeomorphic), lateral (floodplain-river), lateral-vertical (hillslope-river), vertical (surface water-groundwater), and within-ecosystem linkages. Hypothesized relationships between landscape linkages and ecosystem services provided by fresh water are explored that address the role of spatial heterogeneity.

The south Florida ecosystem is used as a case study to show how spatial heterogeneity in this system affects a variety of ecosystem services. Spatial heterogeneity of nutrient sources will influence the location of restoration efforts in the Everglades. In addition, ecosystem services of water supply, water quality, and navigation are influenced by the configuration of the highly interconnected and heavily managed Greater Everglades Ecosystem in south Florida. The socioeconomic and environmental consequences of this connectivity are explored under high and low flow conditions.

Introduction

There is increasing recognition that fresh water is a crucial and imperiled resource (Naiman et al. 1995; Jackson et al. 2001; Baron et al. 2002). Assessments on the state of global water conditions have alerted the public that freshwater resources are seriously threatened and that we need to start thinking about water quantity and quality in new ways (Gleick 1998, 2000, 2002). One innovative approach is the improved integration of the ecological, engineering, social, and economic sectors dealing with water resources, which is resulting in a more holistic approach to water management (Naiman et al. 1998; Falkenmark 1999; Johnson et al. 2001; Baron et al. 2002; Steinman et al. 2002). However, further advances are needed in understanding how best to manage the planet's limited supply of fresh water.

Spatial heterogeneity of water resources is an often overlooked, but potentially important, factor in water management. For example, water bodies are often located at the lowest topographic point in the landscape, allowing them to serve as integrators of landscape processes (Naiman et al. 2002). This spatial placement has been exploited by ecologists, who have used aquatic biota as indicators of ecosystem change (Plafkin et al. 1989; Karr and Chu 1999). This chapter will focus on the concept of spatial heterogeneity and how it can be applied to water management, including a conceptual framework that assesses the potential role of spatial heterogeneity in water management, how the concept of spatial heterogeneity applies to ecosystem services provided by fresh water, and a brief case study that explains the potential relevance of spatial heterogeneity to water management.

Spatial Heterogeneity in Water Management: Providing a Landscape Context

Aquatic ecosystems are characterized by connectivity. Hydrologic connectivity is the water-mediated linkage of matter, energy, or organisms within or between elements of the hydrologic cycle (Pringle 2001). Connectivity can be viewed as an overarching landscape feature of aquatic ecosystems, which can be decomposed into other landscape connections (see below). Both the types of connected water bodies involved in the connections (composition) and the spatial arrangement (configuration) of the linkages help characterize watersheds and set the boundaries for the management of water resources. Table 18.1 identifies six distinct landscape connections with potential bearing on water management, classified based on geographic scale. For the purposes of this chapter, geographic scale is classified as either broad (>1 km^2) or local (<1 km^2), but in reality these scales form a continuum. Thus, some landscape connections apply at both broad and local scales (Table 18.1).