5
Reciprocal Cause and Effect Between Environmental Heterogeneity and Transport Processes

WILLIAM A. REINERS

Abstract

The objective of this paper is to explore the relationships between environmental heterogeneities and the flows and movements that suffuse through all environments. Flows and movements are treated as propagations of ecological influence through environmental space. Propagations are composed of four elements: (1) initiating events or conditions, (2) transport vectors, (3) transported entities, and (4) deposition or impact processes. All four elements have multiple dimensions in type and scale, but vectors are the most convenient means of discussing these phenomena. At a medial level of causation, 10 major vectors are convenient descriptors. These vectors are molecular diffusion; transport by fluvial, colluvial, or glacial modes, gravitational sedimentation, currents (tidal and extratidal), wind (with fire as a special case) agencies; and by electromagnetic radiation, sound, and animal locomotion. Obviously, each of these vector types has different behavior. Propagations can be initiated, or modified by, environmental heterogeneities. But also, propagations can create, maintain, and destroy heterogeneities. Thus, reciprocal cause and effect relationships exist between propagations and environmental heterogeneities. Analysis and understanding of these reciprocal interactions between propagations and heterogeneities requires some understanding of the mechanics of propagations, whether they involve wind, waves, or wallabies. In the same sense, analysis and understanding of how environmental heterogeneities alter propagations requires an appreciation for the global range of heterogeneity types, whether they are ripples, runnels, or run-on patches. Spatially explicit two- and three-dimensional models of propagations in heterogeneous environments are useful ways to develop understanding and, with caveats, to predict how processes and patterns interact. Some of the representational issues of building such models are reviewed in this paper, and three model examples are described.

Introduction

Although ecology has always been a geographically based science, for many decades basic ecological research tended to have a point-model focus. With some important exceptions (e.g., Watt 1947), this was reflected in the emphasis on putatively homogeneous sites, whether stands or watersheds, as the appropriate representation of nature (Wiens 2000; Reiners and Driese 2004). This was not true in applied areas of ecology such as forestry, wildlife, fisheries, and range sciences where spatially distributed representations of nature were imperative. Point models were of little use for predicting habitat usage by deer or the dispersal of white pine blister rust. This perspective has changed for basic ecology in the past two decades, however, as the point-model view of nature has largely given way to a spatially heterogeneous representation of nature (Turner et al. 2001; Chapin et al. 2002; Reiners and Driese 2004). With the advent of new foci such as landscape ecology, conservation biology, and earth system science, and with the practical application of tools for acquiring and managing spatial data, the conceptualization of nature and the practice of basic ecology have made the heterogeneous domain the primary focus (Turner et al. 2001).

A benefit of adopting a spatially distributed view of nature is an easier incorporation of flows and movements into our visualization and treatment of a spatially heterogeneous environment. Transport processes—so intrinsic to the way nature operates—underlie many of the more interesting and important aspects of ecology. Personal experiences tell us that transport processes are influenced by environmental heterogeneity. By stepping around the corner of a building on a windy day, for example, we notice significant changes in our bodily comfort. A spatial approach to ecology now allows us to appreciate, analyze, and model how spatial heterogeneity and transport phenomena are reciprocally related.

The objective of this paper is to review how flows and movements of different kinds affect, and are affected by, environmental heterogeneity. This paper is organized into six sections: (1) how transport phenomena act as propagations of ecological influence, (2) how transport processes are affected by environmental heterogeneity, (3) how propagations may produce, maintain, and destroy environmental heterogeneity, (4) issues in the spatial representation and modeling of propagations, (5) three examples of propagation modeling in heterogeneous environments, and (6) how a propagation perspective might influence our conceptualization of nature and ecology.

Transport Phenomena as Propagations of Ecological Influence

Flows and movements can be generalized as propagation phenomena entailing four components: (1) initiating events or chronic conditions, (2) a