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A framework for interdisciplinary understanding of rivers as ecosystems

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Abstract

Understanding and managing the behaviour of rivers as ecosystems requires holistic, interdisciplinary approaches. However, we lack appropriate frameworks to guide interdisciplinary thinking because disciplinary paradigms lose their usefulness in the interdisciplinary arena. Conceptual frameworks are useful tools with which to order phenomena and material, thereby revealing patterns and processes. A framework for the interdisciplinary study of river ecosystems is presented in this paper. The framework presents parallel hierarchies in the geomorphology, hydrology and ecology of a river with different organizational elements and levels of organization for each discipline. It assigns spatial and temporal scales for each level of organization for the different discipline hierarchies whereby different parts can be distinguished by different frequencies of occurrence and/or rates of change. Integration of the different disciplines, within the context of a particular study, is represented by a flow-chain model that describes process interactions that can change an ecosystem from one state (a template) of biophysical heterogeneity to another (a product). The framework concept is applied by first describing in detail the relevant organizational levels that characterize the different subsystems of the river ecosystem in the context of the problem being addressed. This is followed by the identification of appropriate scales and variables within the different organizational levels. Then the interactions with the products of template/agent of change/controller interactions that may account for any feedback influences are described. A series of examples is provided to illustrate the use of the framework in various interdisciplinary settings.

Keywords: Riverine ecosystems; Conceptual frameworks; Hierarchy; Scale; Interdisciplinary research

1. Introduction

Rivers are complex systems. Their form and behaviour reflect interacting geomorphical, hydrological and ecological processes. While the importance of these interactions is recognized (e.g. Phillips, 1995), solutions to common river problems tend to combine unconnected inputs from the several disciplines rather than taking an interdisciplinary approach. Successful interdisciplinary science requires that the separate disciplines gain a common understanding of the nature of the problem at hand, identify the scales of relevant subsystem components, the underlying processes or phenomena, and the important variables involved. Successful interdisciplinary science requires joining of many areas of understanding into a single conceptual–empirical structure (Pickett et al., 1994).

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A conceptual framework can help different disciplines work together in an integrated way by ordering phenomena and materials and, thereby, revealing patterns (Rapport, 1985). Frameworks serve as scientific maps for new areas of endeavour, where even tentative maps are useful (Pickett et al., 1999), if only because their subsequent improvement provides some measure of progress in integrative thinking. Interdisciplinary river science at present lacks a conceptual framework to bring about commonality and integration. Conceptual models in river science explain, among other things, the influences of processes on channel morphology (Leopold et al., 1964), catchments on streams (Hynes, 1975; Vannote et al., 1980), and the importance of patches in rivers (Pringle et al., 1988). But these present the perspectives of single disciplines only and cannot broadly serve the multi-dimensional decision-making environment of interdisciplinary river science. Individually, they have value but do not provide a basis for ecologists, hydrologists and geomorphologists to integrate their thinking, concepts, and data collection.

This paper proposes a framework to facilitate the integration of disciplinary efforts in the understanding and management of river systems. The framework is based on hierarchy theory, which uses a set of principles to keep track of the complex structure and behaviour of systems at multiple scales (Allen and Hoekstra, 1992). The goal of the framework is to match the description of river form (in the context of a particular problem) with appropriate fluvial processes, so that phenomena can be explained at appropriate spatial and time scales. This will facilitate understanding and prediction of the response of patterns to processes, and the influences of patterns on processes.

2. Underlying concepts

The complexity of river systems challenges many traditional scientific methods. Their multi-causal, multiple-scale character limits the usefulness of the conventional reductionist falsification approach, except when applied at very small scales and within limited domains. Hierarchy theory, however, provides an approach for interpreting river complexity. A hierarchy is a graded organizational structure. A particular hierarchical level (or holon) in a system is a discrete unit of the level above it, and an agglomeration of discrete units of the level below it (Fig. 1A). A particular level in the hierarchy exerts some constraint on lower levels (O’Neill et al., 1986), especially the one immediately below; lower

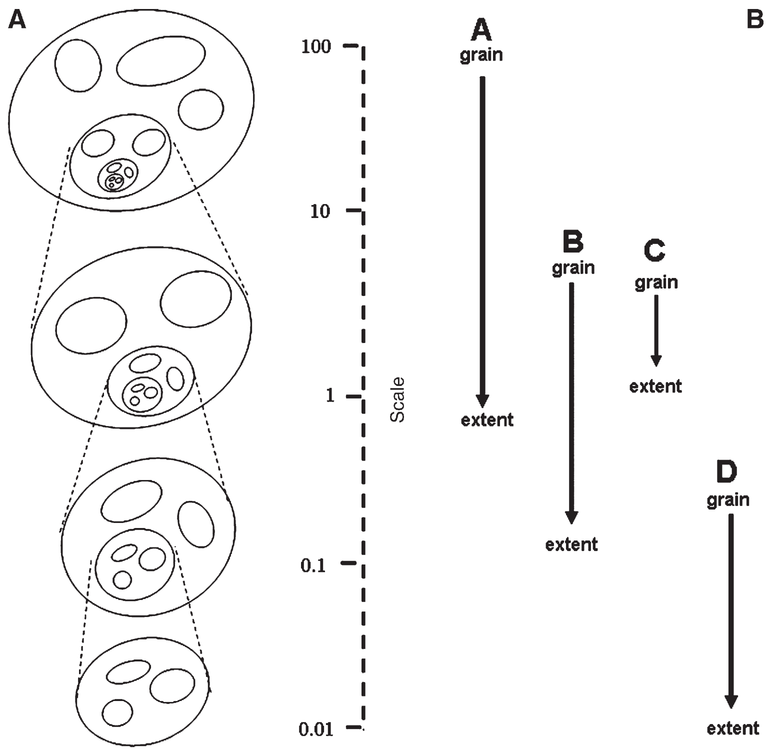

Fig. 1. Nested levels of organization (A) and how they may be related to the grain and extent of scale (B). Scale is presented as being dimensionless as the final scale is dependent on the unique characteristics of individual river systems. The figure can also be used for locating the problem scale within the organizational levels. After Kotliar and Wiens (1990).