River Networks as Ecological Corridors for Species, Populations and Pathogens of Water-Borne Disease

Andrea Rinaldo[1]
École Polytechnique Fédérale de Lausanne, Switzerland and Università di Padova, Italy

Abstract. The Lecture will address recent work at the interface of hydrology, geomorphology and ecology under an integrated framework of analysis -- with an aim for a general theory. I shall touch upon a range of related topics, including biodiversity of freshwater fish in river networks and vegetation along riparian systems, species lifetimes in a tree-like network environment, how river networks affected historic spreading of human populations, and how they influence the spreading of a water-borne disease. Despite the variety and complexity of the ecosystems involved, a unique, coherent eco-hydrological thread is argued to exist where proper mathematical methods allow a unified description of different processes whose linkage is the nature of the environmental matrix, the ecological corridors provided by the fluvial environment. Metacommunity and individual-based models are employed to study hydrochory, population and species migrations, and the spreading of infections of water-borne disease to frame and define the impact of the networked environments acting as a substrate for the biological processes. A general theory emerges on the effects of dendritic geometries on the ecological processes and dynamics operating on river basins that has established, I believe, a new significant scientific field. Insights provided by the theory lend themselves to issues of great practical importance such as integration of riparian systems into large-scale resource management, spatial strategies to minimize loss of freshwater biodiversity, and effective prevention/vaccination campaigns against water-borne diseases. I shall also report on significant case studies facing real-world environmental data. For instance, a description will be given of the observed geographic distribution of freshwater fish species in the Mississippi-Missouri river system, focusing on the size and spatial distribution of geographic ranges. Use will be made of a particular metric of geographic distribution known as environmental resistance, a biogeographic index that quantifies the pointwise average spatial loss of biotic resemblance to identify homogeneous regions of the river basin. Empirical patterns will be compared with the results of a neutral metacommunity model in which local fish communities are interconnected through the ecological corridors provided by the river networks. Because neutral theory assumes that all individuals across all the species are functionally equivalent at a per capita level, the comparison is aimed at quantifying how much of the range patterns are the results of species' similarity rather than species differences, thus searching for an ecological null model for the analysis of biogeographic range. From there, the Lecture will close by addressing how river network topology affects the general features of the spatial arrangement of species. Because the broad patterns of geographic ranges of freshwater fish in the Mississippi-Missouri can be explained simply by neutral dynamics engaged in river topology and competition for resources among species (i.e. without invoking mechanisms that involve asymmetric interspecific interactions), one wonders what general conclusions can be drawn on limits and validity of the neutral assumption in ecology – a hotly debated matter on which hydrologic controls prove relevant («Models are fun and sometimes even instructive»). Perhaps equally important, I shall claim -- hopefully with proper insight -- that the topology of the environmental matrix should be seen even as a determinant for the structure of species lifetime distributions.

[1] Laboratory of Ecohydrology ECHO/IEE/ENAC, École Polytechnique Fédérale de Lausanne (EPFL), (andrea.rinaldo@epfl.ch) & Dipartimento IMAGE, Università di Padova (Italy)