Explaining biodiversity patterns in river networks

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In a study published this week in the scientific Journal Proceedings of the National Academy of Science (PNAS), researchers from EPFL, Eawag and University of Princeton show that the specific river-like network structures of habitats create unique biodiversity patterns. The study is the first to experimentally link river-like network structure with characteristic distributions of species observed in real rivers.

Diversity patterns in river-like landscapes

Biological communities often occur in spatially structured habitats where the connectivity of the landscape directly affects species' movements. This often occurs in dendritic structures, or tree-like branching, that define ecological corridors of great importance in nature. Examples of which include the drainage networks in river basins at the heart of the present research (Fig. A below for a conceptual scheme of a natural dendritic landscape). Riverine ecosystems sustain high levels of diversity of animals and plants. To protect such diversity, it is thus of great importance to understand the factors creating and maintaining it.

In the past, local environmental factors were seen as the most important drivers of the occurrence of organisms. More recent studies have also argued that directional dispersal of organisms constrained by the habitat structure plays a decisive role. However, most of these studies on diversity patterns in rivers either have ignored the specific structure of landscape as a possible causal explanation of diversity or employed simplified spatial structures. A coherent picture on the importance of the river structure emerged across theoretical models and naturally observed diversity patterns for major river systems, like the Mississippi-Missouri, the Amazon and the Rhine. However, experimental evidence linking river-like network structure and species diversity has been lacking so far.

Experiment and mathematical model give consistent results

We experimentally investigated the effects on biodiversity of directional dispersal imposed by replicated river-like habitat-network structures (Fig. A and B). We did so by conducting an elaborate laboratory experiment using aquatic microcosms with microorganisms (protists and rotifers; Fig. 1 in the article and Fig. C below). This simplified system allowed us to causally address the effect of dispersal along specific network structures on diversity with replicated landscapes. We compared landscapes in river-network geometry with homogeneous landscapes, in which individuals could move following an isotropic two-dimensional environmental matrix (Fig. B). We experimentally demonstrated that connectivity in dendritic communities shapes species diversity at both local and regional scales. Dispersal along dendritic landscapes leads to higher variability in local diversity and among-community composition, two of the main biodiversity indicators (Fig. 2 in the article). Our experimental headwaters, the most isolated communities in the dendritic landscapes, exhibit relatively low species richness. However, they also exhibit a high level of among-community diversity, making individual headwaters unique in community composition. This variability is seen as crucial for the maintenance of regional diversity. On the contrary, local dispersal in isotropic landscapes resulted in homogenized local species richness, with little variation between communities.

In parallel to the experiment, we developed a suitable mathematical model of the relevant ecology and compared its results with experimental evidence. Our two-fold approach combining experiments with modeling is especially revealing, supporting the generality of our findings.

Implications

We show that species being constrained to disperse within dendritic corridors face reduced spatial persistence and higher extinction risks. On the other hand, such habitats sustain higher levels of among–community diversity. The implications of our findings are manifold.

Although our experiment and models imply strong simplifications of natural river systems, preventing us to make direct predictions on diversity in specific real rivers, simplification and replication and the reproduction of key connectivity features allow to draw lessons of general nature and careful extrapolation to real systems. Specifically, we suggest that the connectivity within rivers, and thus the landscapes from which river-network structure are formed, are fundamental drivers of biodiversity, essential ingredients for maintaining suitable ecological function and of large-scale water resource management. Modifying connectivity in such networks, for example by connecting river branches by channels or by building dams, will thus directly have consequences on the diversity patterns within such systems.

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https://www.eawag.ch/en/info/portal/news/news-archive/archive-detail/explaining-biodiversity-patterns-in-river-networks