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River networks and ecological corridors: reactive transport on fractals, migration fronts, hydrochory

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Moving from a recent quantitative model of the US colonization in the 19th century that relies on analytical and numerical results of reactive-diffusive transport on fractal river networks, this paper considers its generalization to include an embedded flow direction which biases transport. We explore the properties of biased reaction-dispersal models, in which the reaction rates are described by a logistic equation. The relevance of the work is related to the prediction of the role of hydrologic controls on invasion processes (of species, populations, propagules or infective agents, depending on the specifics of reaction and transport) occurring in river basins. Exact solutions are obtained along with general numerical solutions, which are applied to fractal constructs like Peano basins and real rivers. We also explore similarities and departures from different one-dimensional invasion models where a bias is added to both the diffusion and the telegraph equations, considering their respective ecological insight. We find that the geometrical constraints imposed by the fractal networks imply strong corrections on the speed of travelling fronts that can be enhanced or smoothed by the bias. Applications to real river networks show that the chief morphological parameters affecting the front speed are those characterizing the node-to-node distances measured along the network structure. The spatial density and number of reactive sites thus prove to be a vital hydrologic control on invasions. We argue that our solutions, currently tied to the validity of the logistic growth, might be relevant to the general study of species' spreading along ecological corridors defined by the river network structure.