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Flux: A new building block for ecological networks

Ecosystems are often modeled using weighted digraphs, representing flow of energy or nutrients among compartments. Depending on the model, what a compartment represents may range from dissolved organic matter in a lake, to species with common properties living in a specific area. Flows among compartments may represent predation, uptake, excretion, etc.

Ecological Network Analysis (ENA) enables quantitative study of ecosystem models by formulating system-wide organizational properties, such as how much nutrient cycling occurs within the system, or how beneficial a particular species is to the entire ecosystem (keystone species). Most such properties are defined based on the digraph structure, the flow quantities associated with each edge, and storage values associated with each compartment (node).

While ecosystems seem to be made up of flows among compartments, neither flows, nor compartments can function by themselves. Motivated by Flux balance analysis (FBA, Kauffman, 2003) and metabolic control analysis (MCA), we propose a new building block for ecosystems, called fluxes. A flux is a subnetwork which represent the smallest process within the ecosystem that can theoretically sustain itself. This can be a material cycle within the ecosystem, or a simple food chain in a complex foodweb. Fluxes have interesting properties that render them extremely useful for ecological studies. For example, any ecological network has a unique set of fluxes. And any ecosystem model, steady-state or dynamic, can be expressed as a linear combination of its fluxes.

Identifying important fluxes for an ecosystem model might be as important as identifying important compartments (e.g., keystone species) or important flows (e.g., betweenness measure). We will focus on several quantitative ecosystem properties, and study how they are represented over fluxes. For example, the amount of material cycling that occurs within the whole ecosystem equals the sum of material cycling that occurs within each of its fluxes. This result holds regardless of the size or complexity of the model. We anticipate that other system-wide ecosystem properties are conserved by this decomposition. Finally, we will demonstrate an online tool that computes fluxes for any ecological network model (EcoNet: http://eco.engr.uga.edu).