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Direct, indirect, and nearly always non-linear biological responses to dynamics of the physical stream environment

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The physical-chemical environment sets the stage upon which biological systems operate, and physical models can be used as drivers of some biological processes in streams. However, the manner in which biological systems respond to their physical environment can be adaptive (individuals change their behaviour, populations evolve) and strongly non-linear. We use three examples to illustrate the challenges of linking physical and biological systems, and further how these increase the uncertainty of changes and recovery dynamics in water resources management. Temperature is frequently considered as a "master" variable for biological systems, but responses to temperature affects growth curves (including thresholds at both ends), acclimation, competitive shifts, interactions with their predators, and resources. We use an example of a bioenergetic model parameterised for cutthroat trout to demonstrate the possible range of forms for these functions.

Decomposition and use of leaf litter in streams is a critical function and supports a large fraction of the biological energy used in stream food webs. The dynamics of leaf litter in streams is governed by effects of temperature on rates of decomposition, storage as a function of channel complexity, and hydrology affecting entrainment (or settlement) of particulate organic matter. In addition there are strong reciprocal linkages to the riparian forest that include the kinds of leaf litter, its timing and particle size, stream temperatures, and large wood supplies (structure). Particle size and density of organic matter are additional factors in the complex function of relating organic carbon dynamics to the physical stream system.

Algal production in streams is a function of light, nutrients, flow, temperatures, and interactions with the remainder of the biological systems (consumers). Shifts in these driving variables may not result in any net change in primary production as a function, but there may be strong divergence in structural aspects, i.e., species composition. This may also in turn have feedbacks on transport of fine inorganic sediments.

Finally, recovery dynamics of biological systems, such as recolonisation depends not only on the physical system, but a source pool of individuals capable of reaching sites, as well as appropriate levels of resources and other species with which it interacts. Many processes of the stream system are tightly linked to riparian systems (and vice-versa) and highly interdependent. Management, such as protection of riparian areas, can mitigate some of the potential shifts to extreme conditions from which species, aquatic or terrestrial, may not quickly recover.