Resilience and state change in high-disturbance ecosystems: Investigating how internal processes determine susceptibility to state change

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Ecosystems experience regime shifts in response to a range of both natural and human-induced disturbances. Much of our knowledge about state change comes from ecosystems with relatively benign disturbance regimes (e.g., lakes), yet alternate stable states are more often found in disturbance-structured ecosystems. Given uncertainty about the magnitude, frequency, and timing of future disturbances, it is critical that we better understand the basis for resilience in disturbance-structured ecosystems. We are addressing theories of ecosystem regime shift and stable state resilience by studying aridland wetlands (ciénegas) because they are effectively ecosystems "on the edge"—systems in an environment very nearly too dry for wetlands, yet routinely perturbed by scouring floods. Our general questions are: 1) Can internal processes in ecosystems with substantial disturbance regimes enhance resilience to state change that is driven by exogenous [climatic] perturbations? 2) Is resilience to state change consistent at multiple scales (years to centuries) of hydroclimatological forcing? We are using both contemporary and historical research approaches in ecology, hydroclimatology, and biogeochemistry in ciénega ecosystems in five basins in the southwestern U.S. and Mexico along a flash-flood disturbance gradient. Our experimental work addresses the following central question: Does the allocation of aboveground and belowground plant biomass control the resistance (R) of ciénega ecosystems to flooding or drying disturbance, and thus susceptibility to state change? Central to our research is the hypothesis that enhancing nutrient availability will reduce belowground biomass (absolute and as fraction of total biomass) in aridland wetlands, per resource allocation theory, and that this reduction will reduce the resistance of fertilized ciénegas to flooding and drying disturbances.

We are addressing this question and hypothesis with a four-year research plan centered on the fertilization of experimental ciénegas at three of five sites that span our disturbance gradient. Our primary response variable is an index of aboveground and belowground plant biomass. We are also quantifying: 1) plant community composition; 2) nutrient dynamics in plants, soils, sediments, and hyporheic water; 3) soil/sediment oxygen levels; 4) soil/sediment accretion and erosion; 5) surface and subsurface hydraulics and canopy flow, and; 6) the efficacy of wetland restoration in aridland streams. Our historical research at all five sites is investigating the origination of ciénega development, state change responses to floods and climate variability, and vegetation changes through the late Holocene. We use an existing catchment model to integrate our contemporary and paleoecological analyses in a multi-scalar hydroclimatological view of late Holocene ciénega history. This research addresses fundamental ecosystem theory on resilience, state change, and disturbance in the context of highly perturbed systems. We have adopted a conceptual framework based on a stability landscape defined by two hydrologic axes, flooding and drying, and a third internal process axis represented by biomass allocation in wetland plants. We anticipate that our process-based, interdisciplinary, experimental approach will advance theory on ecosystem resilience and state-change thresholds while also providing practical knowledge on the restoration of ciénega ecosystems.