

Seasonal change of topology and resilience of ecological networks in wetlandscapes

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Wetlands distributed in a landscape provide various ecosystem services including habitat for flora and fauna, hydrologic controls, and biogeochemical processes. Hydrologic regime of each wetland at a given landscape varies by hydro-climatic and geological conditions as well as the bathymetry, forming a certain pattern in the wetland area distribution and spatial organization. However, its large-scale pattern also changes over time as this wetland complex is subject to stochastic hydro-climatic forcing in various temporal scales. Consequently, temporal variation in the spatial structure of wetlands inevitably affects the dispersal ability of species depending on those wetlands as habitat. Here, we numerically show (1) the spatiotemporal variation of wetlandscapes by forcing seasonally changing stochastic rainfall and (2) the corresponding ecological networks which either deterministically or stochastically forming the dispersal ranges. We selected four vernal pool regions with distinct climate conditions in California. The results indicate that the spatial structure of wetlands in a landscape by measuring the wetland area frequency distribution changes by seasonal hydro-climatic condition but eventually recovers to the initial state. However, the corresponding ecological networks, which the structure and function change by the change of distances between wetlands, and measured by degree distribution and network efficiency, may not recover to the initial state especially in the regions with high seasonal dryness index. Moreover, we observed that the changes in both the spatial structure of wetlands in a landscape and the corresponding ecological networks exhibit hysteresis over seasons. Our analysis indicates that the hydrologic and ecological resilience of a wetland may be low in a dry region with seasonal hydro-climatic forcing. Implications of these results for modelling ecological networks depending on hydrologic systems especially for conservation purposes are discussed.