

Early warnings of regime shifts: evaluation of spatial indicators from a whole-ecosystem experiment

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Abstract. Critical transitions between alternate ecosystem states are often preceded by increased variance and autocorrelation in time series of ecosystem properties. Analogous changes may occur in spatial statistics as ecosystems approach thresholds for critical transitions. Changes in spatial statistics near thresholds have been described using models, laboratory experiments, and remotely sensed data, but there have been no tests using deliberate manipulations of whole ecosystems in the field. We previously documented a whole-lake manipulation resulting in a transition to predator dominance, a type of critical transition. The food web of an experimental lake was forced via cascading trophic interactions from a stable state characterized by abundant prey fish, small zooplankton, and high chlorophyll concentrations to an alternative state dominated by predatory fish, large zooplankton and low chlorophyll concentrations. Time series of zooplankton and chlorophyll concentrations provided early warning of the regime shift. Here we test if similar early warning signals were present in space by applying spatial variance and the discrete Fourier transform to spatially distributed prey fish catch data from this regime shift. Prey fish spatial distributions were monitored daily using minnow traps deployed around the lake perimeter. Added predators reduced prey fish populations and altered their spatial distributions. Increases in spatial variance and shifts to low frequency spatial variance were observed up to a year in advance of the shift. There was no response in an adjacent reference lake. Our results demonstrate that spatial signals of approaching thresholds can be detected at the ecosystem scale.

Key words: critical transition; early warning indicators; ecosystem experiment; Fourier analysis; regime shift; spatial variance.

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