Zooplankton provide early warnings of a regime shift in a whole lake manipulation

Michael L. Pace,[a,*] Stephen R. Carpenter,[b] Robert A. Johnson,[a] and Jason T. Kurtzweil [b]

[a] Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia
[b] Center for Limnology, University of Wisconsin, Madison, Wisconsin

Abstract

Regime shifts are massive changes among alternate ecosystem states. Predicting regime shifts is difficult, but statistical indicators such as increasing variance or autocorrelation may provide early warnings of their impending onset. We conducted a 4 yr lake manipulation to test for early warnings prior to a food-web transition by adding largemouth bass (*Micropterus salmoides*) to a lake dominated by small fishes, and thereby drive a trophic cascade that altered zooplankton biomass, community composition, and body size. Declining catches of small fishes were associated with shifts to larger bodied species of *Daphnia*. We measured zooplankton biomass daily in a reference and manipulated lake and calculated variance and autocorrelation of the zooplankton time series using 28 d rolling windows. We asked whether the variance in the manipulated lake (relative to the reference lake) increased and whether autocorrelation approached unity (a value suggested by theory) prior to the food-web regime shift. The variance and autocorrelation of zooplankton biomass were similar between the two lakes in the first 2 yr of the manipulation. During the third year, variance was much higher and autocorrelation approached unity for sustained periods in the manipulated but not in the reference lake. Variance and autocorrelation were similar between the two lakes during the fourth year as the food-web transition moved to completion. The joint response of variance and autocorrelation in year 3 provided an early warning of the food-web transition consistent with theoretical expectation.