Passing the point of no return

Early warning signals indicate impending ecosystem regime changes

By David Seekell

In the field of ecology, regime shifts are massive changes in function and character that occur when an ecosystem passes a tipping point. Regime shifts sometimes have severe consequences for human well-being through losses of ecosystem services, including desertification in arid regions and marine fisheries collapses (1, 2). These changes are difficult to predict and sometimes impossible to reverse (2). For these reasons, understanding how to anticipate and prevent regime shifts is one of the most important challenges faced by environmental scientists (1–3).

Theoretical analyses have identified statistical anomalies, such as increased autocorrelation and variance in time series before regime shifts (1, 2). These patterns are a manifestation of “critical slowing down”—when return rate from perturbation to equilibrium progressively declines before a tipping point (1). My dissertation research evaluated these anomalies as potential early warning indicators for ecosystem regime shifts.

This research was centered around a whole-lake experiment conducted with collaborators on two small lakes in the Upper Peninsula of Michigan. We manipulated the fish community of one lake to cause a trophic cascade—a type of regime shift—and made measurements throughout the food web to determine whether early warning indicators were detectable before the tipping point (2, 4–6). An adjacent reference lake was monitored for comparison.

The experimental lake and reference lake had similar fish communities, with piscivorous largemouth bass (Micropterus

Lake fish regime shift. (A) Positive feedbacks can push either predators (largemouth bass) or prey (pumpkinseed sunfish) to dominance in the study lakes. (B) Average number of fish caught in minnow traps distributed around the edge of the experimental (black line) and reference (red line) lakes. This is an index of prey abundance. The study occurred during four consecutive summers, but here the data are concatenated into a continuous time series for aesthetic reasons. (C) Early warning of the regime shift based on moving-window conditional heteroskedasticity tests applied to chlorophyll-a concentrations from four summers concatenated into a single time series (5, 8, 9). Chlorophyll-a concentration is an index of phytoplankton biomass that strongly reflects the variability generated by the regime shift in the fish community (2, 5). There was early warning for the entire summer the year before the regime shift and until the tipping point was passed during the year of the regime shift.
David Seekell is an environmental scientist based in Sweden. He holds a Bachelor of Science in Natural Resources from the University of Vermont, and a Ph.D. in Environmental Sciences from the University of Virginia. In his Ph.D. research, Seekell developed statistics to provide early warning that an ecosystem is passing a tipping point and is about to undergo a regime change. He is currently an assistant professor of Ecology in the Department of Ecology and Environmental Science at Umeå University. In 2015, he became a Wallenberg Academy Fellow, and in 2016, he received a Science for Solutions Award from the American Geophysical Union.

**REFERENCES AND NOTES**


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