Changes in ecosystem resilience detected in automated measures of ecosystem metabolism during a whole-lake manipulation

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Environmental sensor networks are developing rapidly to assess changes in ecosystems and their services. Some ecosystem changes involve thresholds, and theory suggests that statistical indicators of changing resilience can be detected near thresholds. We examined the capacity of environmental sensors to assess resilience during an experimentally induced transition in a whole-lake manipulation. A trophic cascade was induced in a planktivore-dominated lake by slowly adding piscivorous bass, whereas a nearby bass-dominated lake remained unmanipulated and served as a reference ecosystem during the 4-y experiment. In both the manipulated and reference lakes, automated sensors were used to measure variables related to ecosystem metabolism (dissolved oxygen, pH, and chlorophyll-*a* concentration) and to estimate gross primary production, respiration, and net ecosystem production. Thresholds were detected in some automated measurements more than a year before the completion of the transition to piscivore dominance. Directly measured variables (dissolved oxygen, pH, and chlorophyll-*a* concentration) related to ecosystem metabolism were better indicators of the approaching threshold than were the estimates of rates (gross primary production, respiration, and net ecosystem production); this difference was likely a result of the larger uncertainties in the derived rate estimates. Thus, relatively simple characteristics of ecosystems that were observed directly by the sensors were superior indicators of changing resilience. Models linked to thresholds in variables that are directly observed by sensor networks may provide unique opportunities for evaluating resilience in complex ecosystems.

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