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Manipulating the strength of organism-environment feedback increases nonlinearity and apparent hysteresis of ecosystem response to environmental change

Aurélie Garnier[1,2], Florence D. Hulot[3], Owen L. Petchey[1,4]
[1]URPP Global Change and Biodiversity, University of Zurich, Zurich, Switzerland
[2]Instiute of Marine Ecosystem and Fisheries Science, University of Hamburg, Hamburg, Germany
[3]Université Paris-Saclay, CNRS, AgroParisTech, Ecologie Systématique et Evolution, Orsay, France
[4]Department of Evolutionary Biology and Environmental Studies, University of Zurich, Zurich, Switzerland

Abstract:

Theory predicts that organism-environment feedbacks play a central role in how ecological communities respond to environmental change. Strong feedback causes greater nonlinearity between environmental change and ecosystem state, increases the likelihood of hysteresis in response to environmental change, and augments the possibility of alternative stable regimes. To illustrate these predictions and their dependence on a temporal scale, we simulated a minimal ecosystem model. To test the predictions, we manipulated the feedback strength between the metabolism and the dissolved oxygen concentration in an aquatic heterotrophic tri-trophic community in microecosystems. The manipulation consisted of five levels, ranging from low to high feedback strength by altering the oxygen diffusivity: free gas exchange between the microcosm atmosphere and the external air (metabolism not strongly affecting environmental oxygen), with the regular addition of 200, 100, or 50 ml of air and no gas exchange. To test for nonlinearity and hysteresis in response to environmental change, all microecosystems experienced a gradual temperature increase from 15 to 25 °C and then back to 15 °C. We regularly measured the dissolved oxygen concentration, total biomass, and species abundance. Nonlinearity and hysteresis were higher in treatments with stronger organisms-environment feedbacks. There was no evidence that stronger feedback increased the number of observed ecosystem states. These empirical results are in broad agreement with the theory that stronger feedback increases nonlinearity and hysteresis. They therefore represent one of the first direct empirical tests of the importance of feedback strength. However, we discuss several limitations of the study, which weaken confidence in this interpretation. Research demonstrating the casual effects of feedback strength on ecosystem responses to environmental change should be placed at the core of efforts to plan for sustainable ecosystems.

Keywords: dissolved oxygen, environmental change, feedback strength, hysteresis, nonlinearity, organism-environment feedback, stability, transient state