# Complex Ecological Systems

*Jay Odenbaugh*
*Department of Philosophy*
*Environmental Studies*
*Lewis and Clark College*
*jay@lclark.edu*

In this essay, I will sketch the history of the diversity-complexity-stability debate in ecology, explore the variety of complexity and stability concepts in ecology and their philosophical underpinnings, and consider the rich potential of the concept of resilience in adaptive management. By considering this important debate, we can see how non-linear dynamics is shaping ecology.

The history of ecology is rife with suggestions that as the diversity (number of species in a community for example) increases so should the stability of that community. Pioneers like Charles Elton and Robert Macarthur attempted to provide both empirical evidence and theoretical arguments for this view. There have been several important critiques and of this hypothesis and I will consider several coming from the study of non-linear dynamics.

First, the customary mathematical framework for evaluating this hypothesis inherited from the likes of Alfred Lotka and Vito Volterra is to suppose that the species in a community are at equilibrium and thus their numbers are not changing. Next, we represent perturbations to the community through Lyapunov linear stability analysis. In essence, one looks at exceptionally small changes to this equilibrium and determines if the species populations return to their previous numbers. This technique presupposes the community's dynamics after a perturbation can understood in a linear way and that communities have an equilibrium. Non-linear dynamics and disturbance ecology have challenged both of these points and we now countenance a much richer suite of behaviors including multiple equilibria, basins of attraction, and transient dynamical behavior.

Second, in the earlier seventies, Robert May demonstrated that even when utilizing Lyapunov linear stability analyses, as the number of species, interactions between species, and the strength of interaction increases, the equilibrium stability of a community decreases. Thus, even in a linear dynamical framework the diversity-complexity-stability hypothesis seemed unacceptable. This has lead ecologists to articulate a rich variety of alternative complexity and stability concepts for understanding how communities and ecosystems respond to perturbations. Ecologists now are debating over which of these concepts seemed best suited both empirically and theoretically to describe ecological systems.

One important concept articulated by C. S. "Buzz" Holling which has been receiving much attention is that of *resilience*. Roughly, the resilience of a system consists in the magnitude of a perturbation the system can receive without changing its structure or function. If a community or ecosystem has this property it need not possess a single stable equilibrium but may have may different stable states. Moreover, resilience is a non-linear dynamical property and can be understood with non-linear dynamics. In closing, I will consider whether the notion of ecological resilience can provide a better understanding of what "balance" there is to nature and for managing ecological-social systems in a changing world.