Agronomy 375/Environmental Studies 402 - Systems Thinking

Lecture Notes for Oct. 10, 2018: Resilience and Adaptive Cycles

I) Intro

A) What is "Health" for non-human nature. List some words associated with it, but don't use any terms that refer to humans or human uses. Review and discuss the list.

B) The environment you are describing is a system that has material and energy flows, different spatial and temporal dynamics, biological and non-biological components, and lots of feedback. How do scientists researching that system make sense of it? They try to describe and document those relationships. But do they have an answer for what is a "healthy" non-human environment?

II) Overview of readings (what are authors trying to do?)

- Goal of *Panarchy* book is to understand how change in adaptive systems (like ecosystems _or_ human social/economic systems) happens and how to understand interactions between different types of systems (economic, ecological, institutional).
- Authors interested in this because they are interested in sustainability, natural resource management, and governance of natural resources. Authors are ecologists, which shapes their world view.
- What are examples of the "problems" they are concerned with? (Fisheries mgmt.., pest control creating superbugs or pest outbreaks, proper range management, bringing back rare species (whooping cranes), initial management success followed by agency rigidity, others???)
- Features of these kinds of problems: a focus on "solving" one aspect of the problem leads to unintended consequences, sometimes resulting in the potential for system collapse (e.g. – managing for maximum sustained yield of a fishery, or managing a flood plain with dikes and dams to prevent flooding which opens the floodplain for development (causing even more damage when the inevitable 100-year storm overwhelms the flood control system)
- Often people's unexamined "models" of nature are part of the problem – we expect natural systems to behave in certain ways. You demonstrated this with some of the words you used to describe the "healthy" environment.

II) Caricatures of Nature/Models of environment/Myths of environment (pp 10 – 14) (use slide)

III) Goal of authors is to create a heuristic theory that helps us to understand these types of problems and in particular to not just understand change within systems, but to understand how systems themselves change, collapse, and stabilize. What happens when you pave paradise and put up a parking lot? What happens when a beaver dam floods a field? What happens when a rural hospital closes?

IV) To think about this, we need to define some terms like stability. What does "stability" mean in nature? We partially answered this with our discussion of "health" in nature. And if we're concerned with sustainability in all of its meanings we need to be able to answer the question of what is a stable, healthy natural system. What do you think it means?

A) Panarchy authors looked at the features of ecosystems without humans to help define what "stability" might mean. What are some of the features they see in natural ecosystems that have to be accommodated in any definition of stability?

- Episodic change – periods of slow accumulation punctuated by sudden releases and reorganization of the biotic legacy. Examples? (succession followed by a hurricane. Stability of ecosystem on Isle Royale followed by moose arriving followed by wolves arriving, etc.). Temporal scale of change is different for different phases of the system.
- Patchy and discontinuous spatial attributes at all scales from the micro-to the very large. Nature is "lumpy" in ways that concentrates certain resources and opportunities. This is controlled by biotic and abiotic processes (e.g. – bear cam in Alaska – shows a place where bears accumulate at a particular waterfall to eat salmon. River is a food and mating resource for salmon (biotic feature), waterfall (abiotic feature) concentrates the salmon at the bottom which makes it a "patchy" food source for bears). Scaling from small to large is not a continuous process – there are forces that constrain the aggregation of resources.
- There is no single "equilibrium" for an ecosystem where some feedback loop keeps it stable. Rather ecosystems have multiple equilibria for different groups of organisms and states of the system, and it is the normal variability of these that provide structure, diversity, and stability to the overall ecosystem. Some parts are accumulating while others are regenerating (example of Lake Mendota and nutrients) (predation, reproduction, nutrient cycling, stochastic external forces, etc.).
- These ecosystem features mean that human interventions that use fixed rules for achieving constant yields out of ecosystems will inevitably cause the system to lose resilience (i.e. – be unable to absorb a disturbance that would previously be OK).

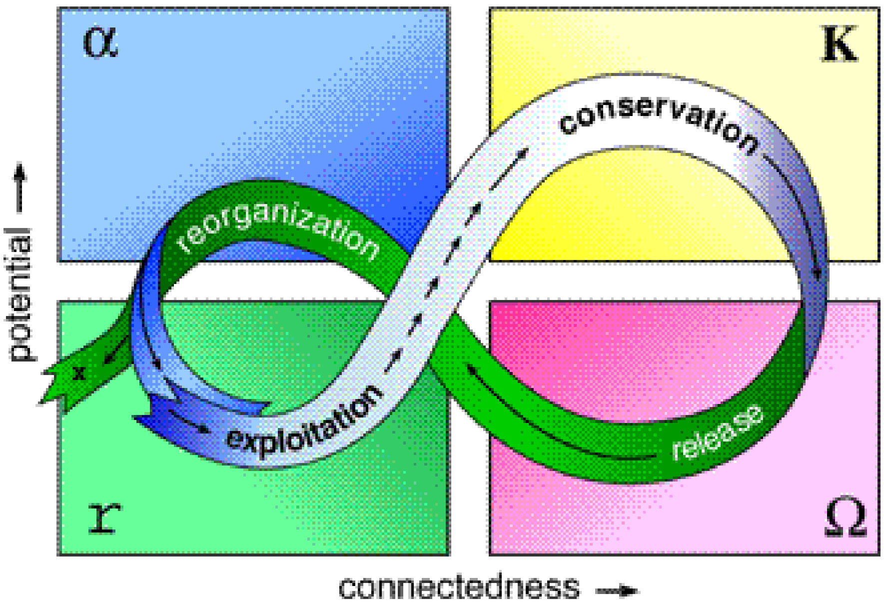
B) If these are the features of ecosystems then what do we mean when we say we want to have some stability or sustainability when we interact w/ these natural systems? Hollings and Gunderson note two kinds of stability. Think of this also as sustainability.

1) Efficiency of function (engineered stability or resilience)

2) Existence of function (ecosystem stability or resilience)

C) Panarchy argues that both of these aspects of stability are important, but perhaps at different times in the development of a system. Returning to myths of nature, there is evidence that nature is not chaotic or anarchic, but there is also evidence that it is not balanced either. There is homeostasis or feedback, but it doesn't always create engineered, efficient, identical stability. So it seems like nature is resilient over time, but that too is only a partial story, since there are always forces that can overwhelm that resilience (e.g. – a forest fire destroys the resilient forest and replaces it with a very different ecosystem). So we need a deeper model of Adaptive Resilience (see the Adaptive Cycle image)

V) The adaptive cycle: A heuristic model to help you structure your thinking about biological and social systems when you're trying to work on problems of sustainability.



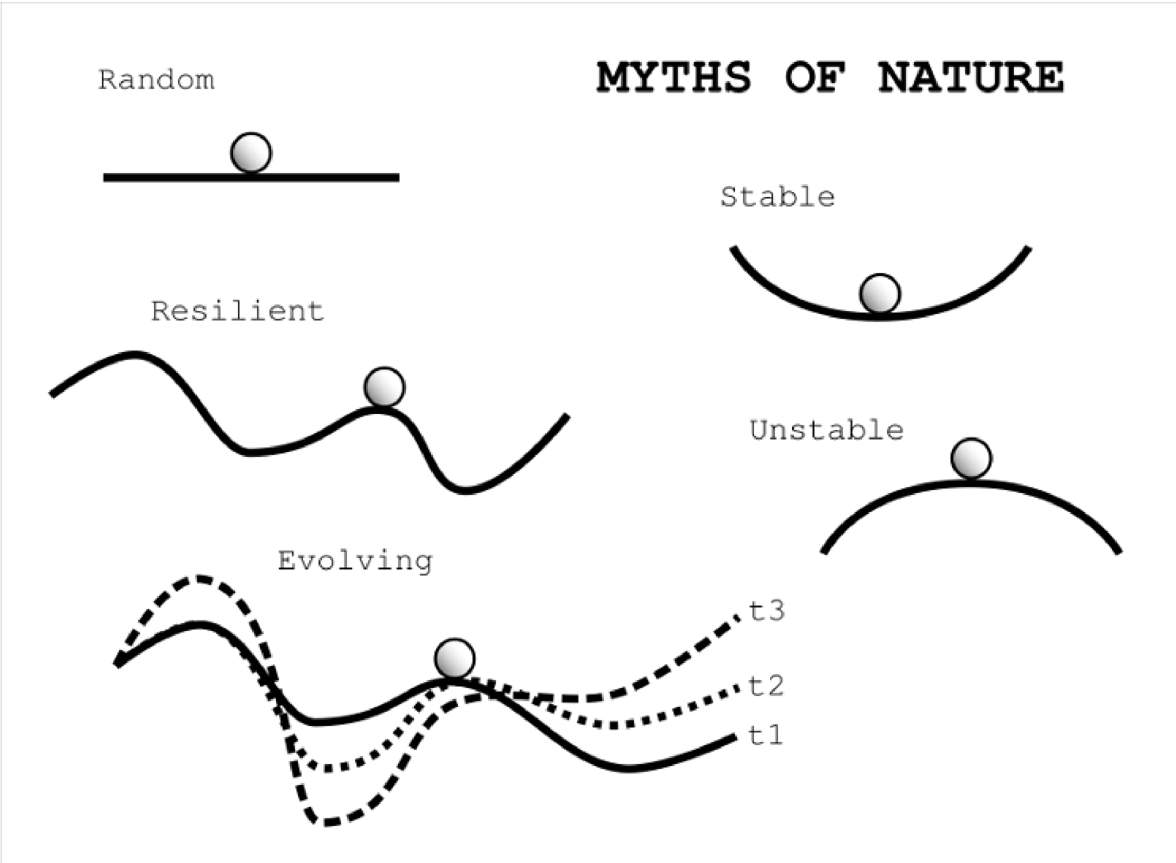
A) Three properties shape the pattern of dynamic change – potential sets limits on what is possible (resources, energy, physical space, etc.). Connectedness determines how much feedback there is and how much the system self-regulates (as opposed to being subject to external variability). Finally Resilience determines how vulnerable a system is to unexpected disturbances – it is the capacity of the system to experience disturbance and still maintain its functions and controls.

B) The book claims that almost all complex adaptive systems, both human and non-human, have these characteristics and evolve in this way. This is not a predictive model, but instead is designed to help you think about a biological or human system in a dynamic way. What do you think? Can you apply this heuristic usefully to a problem you're interested in?

VI) Exercise: divide into six groups of 4 (Liam provides names).

A) Choose an environmental change that you are all somewhat familiar with (e.g. – a beaver dam flooding a field, a lake being loaded with nutrients from agricultural runoff, a rainforest being cut down, etc.) Take a few minutes and use the "Adaptive Cycle" heuristic to discuss that environmental change, and tell us where in the cycle you think the change is happening. Do you think the system is resilient or fragile? Why? Will the system adapt to the change, or will it collapse and reorganize? Report out your discussion.

VII) Next week on Thursday, Oct. 18 we will give you team time to start work on your group projects. PREPARE IN ADVANCE so you can have productive time together in class. We will be here to answer questions.



The first model, “**Nature random**” or “**Nature flat**“, expresses the worldview of a nature without feedbacks or nonlinearities. Changes in this world are driven by random causes, natural or political, and it is therefore a world where humans can do as they please to satisfy their needs, with no risk of triggering undesirable irreversible processes. The ball just moves in a flat terrain, going wherever some random force pushes it.

“**Nature stable**” expresses the view that the world is largely in balance, a static world dominated by negative feedbacks equilibrating any change. This is the worldview that emphasizes maximum yields and believes that we can optimize things to navigate turbulent times.

“**Nature unstable**” or “**Nature anarchic**” is the opposite worldview, where Nature is in delicate balance and extreme caution is needed not to push it away from it. This is the mental model where the precautionary principledominates, and is the worldview held by many environmental organizations.

“**Nature Resilient**” is a step forward in our understanding of Nature, it encompasses the previous three views. It relies on the lessons from the science of complex systems and dynamical systems applied to natural science. A resilient world is one in which several dynamical basins of attraction exist, where a given part of nature might be forced to move to a neighbouring basin by human intervention, or by changes in variables at larger scales of time and space. In this worldview, a perturbed ecosystem can flip to a different state, a move that is fully admissible under the prevailing environmental conditions, although possibly unknown and probably not pleasant for its inhabitants and users. An example of this is the often observed transition of grasslands to dry unproductive woodlands due to heavy overgrazing (Australia, Patagonia).

"**Nature evolving**" is presented as the last frontier. It depicts an even more complex world than "Nature resilient", one where the dynamical landscape changes with time. Gunderson, Holling and Ludwig convincingly argue that this view might be the one closest to our real world, and the one that we should be exploring to assess our impacts on Nature and evaluate our chances for long term survival in the Anthropocene. It is also the one worldview that is least accessible to our intellects, the one that poses the greatest challenges to understanding and prediction, where intuition might not longer serve us so well.

I believe that these models capture wonderfully well some of the most common sets of beliefs that people use to summarize and classify the behaviour complex natural systems. Even if they are just overly simple caricatures, they also show us that having a look at our often unchallenged mental models can be a worthy exercise that can teach us lessons on how to approach Nature in more harmonious ways.