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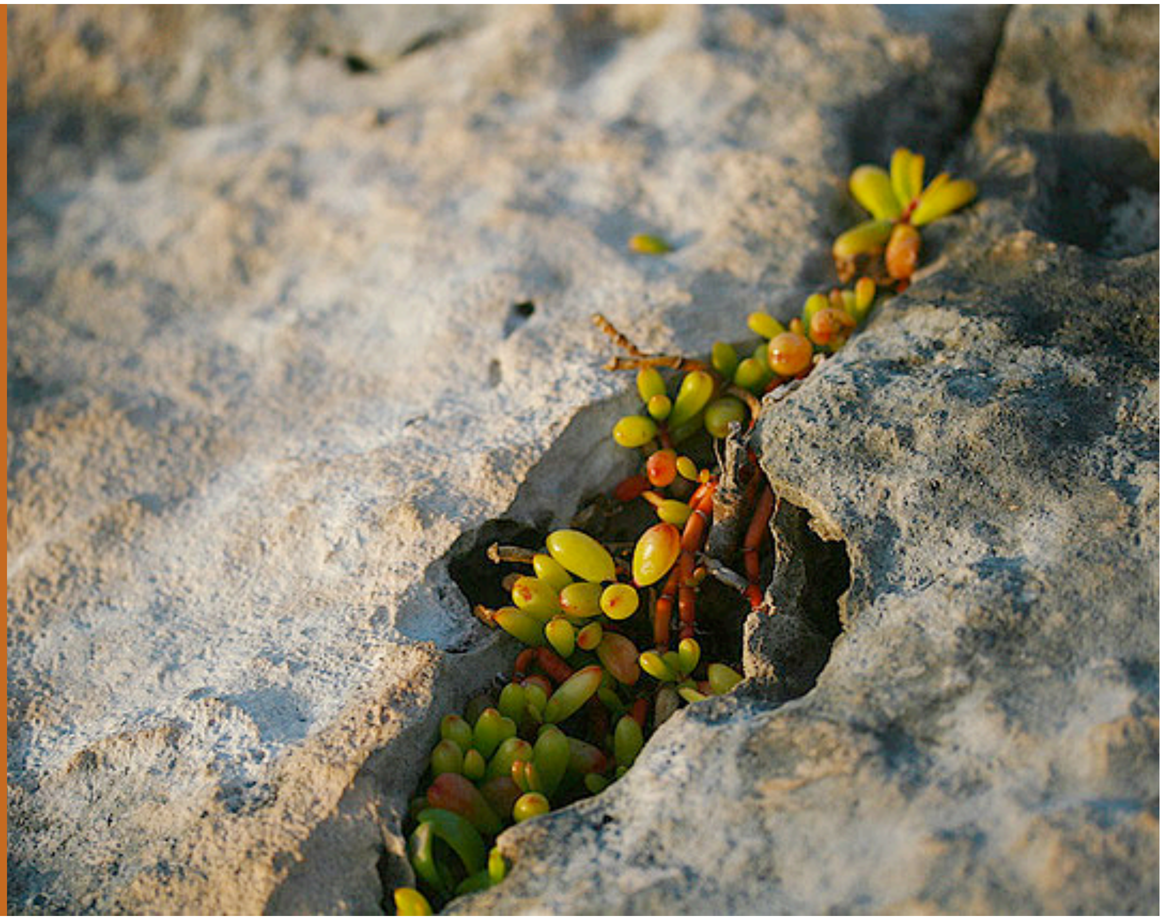

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Special Issue: Resilience

Editor's Note

By Bob Lalasz

Is "resilience" the kind of concept that, as Supreme Court Justice Potter Stewart once wrote about a less savory noun, "I cannot define it, but I know it when I see it?"

Decidedly not, one hopes, at least for conservation. And yet Rebecca Benner, the director of conservation science for the Conservancy's North Carolina program, writes in her opening essay in this issue of *Chronicles* that not only are conservationists seemingly all overthe place about the definition (and how it differs from "adaptive capacity," for instance), but that conservation work incorporates and responds to ecosystem resilience in very different ways, applying widely diverging approaches to different ecosystems, and perhaps failing to account for people altogether in doing so. Can it really be this muddled? And what are the dangers if it is? I asked five Conservancy scientists to respond to Becca's questions, and...I'll let you decide whether the picture is any clearer after you've read their answers. Is Mark Anderson's "options and alternatives" rubric both flexible and firm enough a foundation upon which to go forth and conquer? Does Craig Groves' advice to ignore the divergent definitions and to implement thoughtfully in your local context work? Is the solution in Peter Kareiva's formula (and embrace of data), Stephan Halloy's sense of "pop," or Rod Salm's comfort with the uncertainty inherent in a fast-moving field? Or are you still confused? If you have thoughts, please turn them into letters and submissions to *Chronicles*.

If life is a party, science is too often the wallflower — making brilliant asides about the music, guests and food, but generally not the one to push back the furniture and lead the conga line. So it's good for science at TNC to put on a show from time to time — to celebrate some of the intellectual firepower and innovation we bring to some of the world's toughest conservation problems. That's why Central Science is putting on ScienceFest, two days of talks and debate by about 20 TNC scientists and partners that DC-area staff and other interested partners can attend in person and TNC staff anywhere can watch via simulcast or afterward on tape. The agenda is close to final; if you don't have access to the TNC intranet and want to see the list of speakers and talks, email me and I'll send you a copy.

I put the lineup for ScienceFest together quickly, reaching out to people I knew and knew by reputation as I tried to represent the field, global teams and Central Science while also maintaining an informal vibe. It's not meant to be a best-of-the-best — I didn't have the capacity to do a call for talk proposals and sift through them; so if you're wondering why you weren't asked, blame it on me. If this succeeds and people enjoy it, we'll do it next year and broaden it. But I think any event that ranges from hydropower by design to surviving the population bomb to whether easements will bankrupt conservation to why the future will be rainier but drier has a fighting chance to be a winner. **SC**

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1. To bring you the latest and best thinking and debates in conservation and conservation science;
2. To keep you up to date on Conservancy science — announcements, publications, issues, arguments;
3. To have a bit of fun doing #1 and #2.

Editor & Submissions Bob Lalasz

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Jon Fisher
Patience and Precision: A Call for Caution in Climate Communications

By Jon Fisher, spatial data analyst, Central Science, The Nature Conservancy

Image: Taxi terminal, Hoboken, NJ, flooded after Hurricane Sandy. Image credit: That Hartford Guy/Flickr through a Creative Commons license.

Many scientists in the conservation community get extremely frustrated when climate skeptics take news that seems to confirm their worldview and hold it up as "proof." For example, thickening Antarctic ice is sometimes taken as "disproving" climate change, even though the ice gain is much less than ice loss in the Arctic and is expected to be short-term, anyway.

But sometimes we have trouble resisting similar temptation. For example, Hurricane Sandy has prompted a lot of speech about how, thanks to climate change, "weather on steroids" is the "new normal." It even prompted New York City Mayor Michael Bloomberg to make a last-minute endorsement of President Obama on grounds of his ability to address climate change more effectively. Many scientists have endorsed these statements and have called for using Sandy to push for greater action, not just on disaster risk reduction, but toward reducing carbon emissions.

The terrible destruction Sandy inflicted on millions of people feeds this urgency. But while such urgency may fit in with conservation's message about climate change, I have two questions that I think we as scientists should consider asking before we support the "new normal" kinds of statements:

1. Has enough data come in yet for this claim to be considered "scientific consensus," or is it simply a plausible hypothesis that needs further study?

2. Even if the statement is *generally* true, is it *precisely* true? For example, "climate change is causing more extreme weather" is generally true (as there is solid evidence for climate driving increased frequency and intensity of certain types of extreme weather, like drought). But applying that statement to Sandy is tantamount to saying "climate change will cause more storms like Sandy" (which arguably does not currently represent scientific consensus).

We often add the caveat that any *particular* storm isn't *caused* by climate change, but that doesn't stop us from implying a connection. The science journalist Eric Berger has an interesting post on this topic, where he points out that there is no discernible effect of climate change on hurricane activity at present. Climate models do in fact predict that by 2100 we will see a *decrease* in the frequency of tropical cyclones along with a small increase in intensity (see the Berger post for an overview, get another interpretation perspective, or carefully read the actual publications on which these articles are based: http://www.nature.com/ngeo/journal/v3/n3/pdf/ngeo779.pdf and http://www.agu.org/pubs/crossref/2012/2012GL053360.shtml and http://www.sciencemag.org/content/327/5964/454.full and http://www.ipcc-wg2.gov/SREX/images/uploads/SREX-SPMbrochure_FINAL.pdf). That's a very different prediction from "storms like Sandy are the new normal," which says that the impact is already here and ignores how many factors went into creating a very unusual storm.

My argument isn't in any way a denial of climate change, or even that climate change is fueling several kinds of extreme weather. Much good research shows an increase in heat waves and drought correlated with climate change (the IPCC rates both assertions as medium confidence). There's even a fair amount of work showing that more intense storms are a plausible effect of climate change for a variety of reasons (changes to jet stream patterns, warmer surface water), and we can expect that sea-level rise will eventually lead to real increases in storm surges. But it's sloppy to lump together all "extreme weather," or to mix up what has been shown with what is plausible, or to confuse what we expect will happen eventually with what is happening now.

"Setting expectations that we will see more storms like Sandy in the near future seems to me like playing a dangerous game — a confusion of weather and climate that's akin to shouting "the sky is falling" without yet having the data to back that up."

It is obviously prudent for coastal communities to prepare for the hazards of storms, and to consider ecosystem-based adaptation strategies where that's appropriate. But the "new normal" rhetoric will only be an effective long-term communication strategy for TNC *if* our predictions hold true. Setting expectations that we will see more storms like Sandy in the near future seems to me like playing a dangerous game — a confusion of weather and climate that's akin to shouting "the sky is falling" without yet having the data to back that up. The IPCC has carefully adjusted their confidence in their findings as new science has come out, and we should consider taking the same approach. **SC**

Special Issue: Resilience
What Do We Mean by Resilience? And What Do We Do About It?

By Rebecca Benner, director of conservation science, The Nature Conservancy in North Carolina

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When I first approached the prospect of writing for *Chronicles* on resilience and conservation, I had lofty goals. I'd planned a synthetic essay that teased out the myriad and often confusing ways TNC and conservation have defined and applied the term, thinking I could generate discussion and perhaps even debate. But my research and thinking simply generated more and more questions. So I present those questions here in hope that they spur others to clarify what we, the Conservancy, mean by resilience in nature and, perhaps more importantly, what we plan to do about it.

This isn't just an academic exercise. At least for me, the lack of clarity is something I confront each day in my relatively new position as director of science for The Conservancy's North Carolina program. Soon, our team will have in our hands two resilience analyses — terrestrial (led by Mark Anderson and his team) and freshwater (modeled after Mark's resilience analyses). And the task before me and my colleagues here in North Carolina is: What should we do with these analyses and soon, so that the data and analyses do not go stale? What is our plan? What is our objective? *Why* are we doing these analyses? It's not simply to show us where resilient places are. But for now, "where" is all that we have.

A Confusion of Terms?

Though lots of work has been done to define resilience, for me, at least, it's still muddled with other terms, like climate adaptation. I suppose that makes sense; an ecosystem's adaptive capacity is a good measure of its resilience. The things we talk about with climate adaptation are similarly things we discuss for resilience — e.g. connectivity, climate refugia, conserving the stage, maintaining ecological function and processes, etc.

So my first question: Are these concepts — adaptive capacity and resilience — synonymous? And if not, how should the Conservancy define resilience? If we define it, it will help us streamline how we assess it. In light of our whole systems work, this synchronicity is increasingly important.

Building, Enhancing or Protecting Resilience?

Once we have the analyses telling us where resilient places are, what do we do with that resilience? Are we building it in places that lack it? Enhancing or protecting it in the places it exists? If the answer to the above question about adaptive capacity is "yes," then perhaps we use the increasingly discussed climate adaptation strategies for resilience strategies. (For an example, see the Yale Mapping Framework mentioned in the August *Chronicles* by Craig Groves.)

But even then, should we take similar approaches in marine, terrestrial and freshwater systems? In each system, we seem to have slightly different emphases…or we have yet to define an emphasis at all.

"If these systems are indeed resilient, why would we work there? Why wouldn't we instead work to build resilience in less resilient areas that are still critical for biodiversity? Of course, that question begs another, more fundamental one: Can we build resilience?"

In the marine world (of which I admittedly know the least about), we talk about *building* resilience. We conserve mangroves to build coastal resilience; we create marine protected areas to increase the resilience of coral reefs. There seems to be discussion about how and if these strategies build resilience; but regardless, to my knowledge there is at least a general consensus around the main goals: *building or enhancing* resilience.

But regarding terrestrial ecosystems, I hear talk of *protecting* resilience — the idea that we should identify resilient systems and then purchase a full or partial interest in them. This exposes a contradiction to my mind: If these systems are indeed resilient, why would we work there? Why wouldn't we instead work to build resilience in less resilient areas that are still critical for biodiversity? Of course, that question begs another, more fundamental one: Can we build resilience? The major threat I can think of that could make a resilient system not resilient is urban development. So if there is a credible threat of development, perhaps the best strategy is to acquire some form of interest in the land. But in some ways, that approach also depends on what we care about. If we want to protect a particular species, it will likely move as climate changes. So we may then own a presently resilient ecosystem that will eventually look totally different. Is that what we want?

Another possibility: Instead of conserving or protecting the resilient core of a system, could we try to build resilience around that nucleus? Again, the success of this approach clearly depends on the threats to that system. But should we be trying to grow our work in conservation finance, ecosystem services, environmental education and other types of conservation approaches that work directly with people to improve their management of the land and thereby create resilient buffers around resilient ecosystem cores? And is the answer to all the above questions simply "yes" — do any or all of it, depending on the situation? Which begs yet another question: Is resilience a site-specific topic, meaning there is no point in creating a generalized framework?

How Do We Integrate People Into the Resilience Calculus?

Moving to freshwater, the answer is no clearer, and while people factor into the other two systems, too, here it becomes particularly glaring — whom are we building resilience for? Can we build resilience in freshwater systems without considering both biodiversity and people? Human needs for water and therefore their uses are only going to increase. Freshwater resilience for biodiversity requires environmental flows. Freshwater resilience for people requires the availability of abundant clean water. So to build resilience in freshwater systems, should we be focusing on the intersection of these two elements — or developing strategies that somehow ensure both? To elaborate: In each system in which we decide to work to build resilience or conserve resilience, should we be working on terrestrial riparian strategies, flow strategies *and* water-use strategies (e.g. water footprinting)?

Definitions of resilience abound. And we increasingly know where resilient systems are. But I think the conversation is much less well researched as concerns which definition is most useful for conservation and how we should integrate our growing knowledge into our practices. If we use different definitions and conduct analyses accordingly, we won't be able to work across state or country boundaries or across whole systems. And even if we have a consistent definition, if we don't put our heads together to come up with a framework for how to use such analyses, all we'll have is the analysis. We at least need a good mechanism to share lessons learned and what others are doing about resilience. Data without use quickly becomes antiquated.

I want to use the analyses I have coming my way, but strategically and in ways that make sense. So what are those ways? As promised, lots of questions; but I hope ones that will provoke answers. **SC**

Special Issue: Resilience
Landscape Resilience = Options and Alternatives

By Mark Anderson, director of conservation science, Eastern North America Division, The Nature Conservancy

Sandhill ecologist Aldo Leopold captured the concept of ecological resilience in one elegant 1949 statement: *"Health is the capacity of the land for self-renewal. Conservation is our effort to understand and preserve this capacity"* (Leopold 1949).

More than 50 years later, Lance Gunderson defined resilience as nature's *"capacity for renewal in a dynamic environment"* (Gunderson 2000). Intentionally or not, Gunderson linked his definition to Leopold's while updating it to incorporate the reality of change — a recognition fundamental to today's practice of conservation.

Many ecologists, most notably C.S. Holling (1973), have tried to pin down the concept of resilience and identify the mechanisms that create it; but its elusive character is familiar to anyone who follows politics or watches sports. In these arenas, resilience is characterized by surprises and unexpected twists — the crushed candidate who rebounds in a wholly unexpected way, or the team that rises when their star goes down and a bunch of previously overlooked players suddenly catch fire. In these cases, the expected results didn't occur because somewhere in the mix there were *options and alternatives*. Such options and alternatives build resilience in the ecological realm as well.

"In politics or sports, expected results don't occur because somewhere in the mix there were *options and alternatives*. Such options and alternatives build resilience in the ecological realm as well."

In our work on the resilience of eastern landscapes of the United States to climate change (Anderson, Clark and Sheldon 2012, Anderson and Ferree 2010), we have focused on identifying the factors that create options and alternatives for species and processes *within places*. The distinction is important: the attributes of resilience differ depending on whether you are focused on species and ecosystems, or on enduring physical landscapes. The question we have grappled with is: which factors allow a landscape — defined as geophysical setting — to sustain ecological function and maintain a diverse array of species places even as the climate changes? It's a great conservation question, because those places with inherent properties that build resilience will likely also be natural strongholds for species and nature into the future.

Are there identifiable factors that create options for species and processes within places? At least two characteristics have emerged in the literature based in on-the-ground evidence, and they are related to how complex and permeable a particular landscape is.

Complexity

Complexity refers to the way topographic and elevation diversity parse the regional climate into an array of microclimates that in turn provide climate options for the extant species. Consider a landscape with hot southern slope faces, moist cool coves, and depressed basins that accumulate moisture; the temperature extremes within these local climates can be greater than the regional mean and variance. Stuart Weiss's work in the California foothills (Weiss et al. 1998) and Patrick McMillan's in the South Carolina mountains suggests that these topo-climates are a key to the persistence of plants and animals within these settings — McMillan recorded temperatures as high as 105 degrees F. on a south slope, but only 73 degrees F. on the connected shady north slopes at the same time (McMillan pers. com). Of course, hikers in the New England forests have long known they can store their beer in talus-formed ice caves on a hot August day and return to find it cold and ready for consumption, sharing space with spruce and snowberry more typical of farther north. Species persist in a changing climate by taking advantage of this array of microclimate options when available within their local landscape. The concept has now been coined as "microclimatic buffering" (Willis and Bhagwat 2009). And as climate scientists fit topographic diversity into their models, this buffering is being found to slow down the velocity of climate change's effects on a variety of species (Luoto and Heikkinen 2008, Loarie et al. 2009).

Permeability

How *permeable* a landscape is with respect to its natural processes and ecological flows is a second factor in creating options. By definition, resilient landscapes are dynamic and will rearrange their components to take advantage of microclimates and species turnover. In highly fragmented landscapes, contrasting uses such as development, roads or high-intensity agriculture create resistance that disrupts, restricts and channels natural movements. The ultimate effect is reduced options. However, the permeability of a landscape can be increased depending on how the matrix lands are managed, how farming is practiced, how development is zoned, how roads are planned. The interplay of resistance and permeability is a ripe area for conservation action and research.

Resilience and Change

"Increasing resilience by increasing options for species and processes is not the same as knowing what is going to happen."

Finally, increasing resilience by increasing options for species and processes is not the same as knowing what is going to happen. In our work for the eastern United States, we defined resilience as the ability of a place to sustain ecological function and maintain a diverse array of species. But how the communities actually change — which species will thrive and which ones won't — is dependent on a myriad of interactions, disturbances, starting conditions and arbitrary events. If the outcome is completely predictable, then there must be very few options or alternative paths available to the inhabitants…which is a good definition of a vulnerable, non-resilient site. Still, I hope even the vulnerable site will have some surprises in it. Sixty-three years after Leopold made his statement, I think we still have a long way to go to understanding and conserving the capacity of the land for self-renewal. SC

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Special Issue: Resilience

Moving Beyond the Meaningless: Advancing Resilience and Other Adaptation Approaches

By Craig Groves, director, Conservation Methods Team, Central Science, The Nature Conservancy

In his 1946 essay "Politics and the English Language," George Orwell criticized the trend of using meaningless words in politics and other disciplines, noting that "language can also corrupt thought." Rebecca Benner's essay on "resilience" is a great highlighting of such word corruption — a corruption that has been noted in other conservation quarters recently.

For instance, in their recent review of the climate adaptation literature, Patty Glick and colleagues at the National Wildlife Federation wrote: "Unfortunately, the term resilience is being used so broadly and indiscriminately — and proffered so often as an adaptation panacea — that its utility as a meaningful conservation goal is being undermined" (Glick et al. 2011). They go on to suggest that practitioners must ask "resilience of what, to what" and (citing Zavaleta and Chapin 2010 as well as others) define what the core attributes or functions of a system are that make it resilient. And Jodi Hilty and WCS colleagues make a similar point in their 2012 book *Climate and Conservation* about how the term often lacks any explicit meaning (Hilty et al. 2012).

To complicate matters further, both "resilience" and "adaptive capacity" (another term that Rebecca notes confusion with) are terms routinely used in the social and ecological sciences in relation to adaptation — the former referring to human communities, the latter to ecological ones.

Rebecca can take solace in the fact that there is considerable confusion about resilience in the scientific community. At the same time, there is general agreement that resilience represents a component on a spectrum or in a toolbox of adaptation approaches that include *resistance* on one end (the ability of species or ecosystems to resist forces of climate change and maintain current values); *resilience* in the middle (the capacity of a system to absorb climate impacts without changing states, such as from forest to grasslands); and a *response or transformation approach* on the other end (actions that assist transitions of ecosystems or human communities to a different state).[1]

There is also general agreement (based on the work of the IPCC) that *adaptive capacity* can be defined as an innate quality of a species, ecosystem or human community to accommodate climate impacts with minimal disruption.[2] Adaptive capacity is also related to the concept of vulnerability.

Conservationists, therefore, try to build or enhance resilience through *an approach or set of actions for adaptation*. These actions will vary, of course, depending on the nature of the ecosystems, especially whether it is terrestrial, freshwater or marine. Elizabeth McLeod and TNC colleagues, for example, defined resilience and outlined a set of actions for designing MPA networks to help build resilience. Similarly, TNC's Global Marine Team, NOAA and other partners have built a web mapping application (Coastal Resilience) to help communities respond to sea-level rise by using natural ecosystems as one defense.

Different definitions of resilience are likely to persist, and in as organization as large and diverse as the Conservancy, I wouldn't spend much energy trying to bring consistency to how it is used. Instead, Rebecca, I'd spend your time trying to thoughtfully advance the resilience analyses of Mark Anderson and colleagues and other adaptation strategies through on-the-ground implementation.

To do that, I'd first make sure you understand the analyses and the adaptation approach that underpins them ("conserving the stage" plus some sophisticated landscape "connectivity and permeability" analyses); the many assumptions behind these analyses; and the degree to which those makes sense in North Carolina's setting.[4] Be forewarned, though: The scientific community is anything but settled on this approach as THE (or the only) path forward; there will be a symposium on this topic at next summer's SCB meeting in Baltimore.

Second, if the analysis hasn't been done already, I would use Climate Wizard and other tools to examine what impacts climate change may have on the biodiversity and ecosystem services you care about in North Carolina (much as you and others did in the Climate Clinic). Then I would step back and ask where you might need to revise your conservation goals and projects in light of these likely impacts *as well as other land-use changes that are having an impact on these resources*. Finally, I'd then consider what actions are needed to implement the results of the resilience analyses and what other adaptation approaches may make sense as well.

There you have it — a few answers to many questions that may be of some assistance to your team in moving forward. **SC**

Notes

[1] See Peterson et al., *Responding to Climate Change in National Forests: A Guidebook for Developing Adaptation Options* (2011) (USDA Forest Service General Technical Report PNW GTR-855) for good examples of management actions that reflect resistance, resilience and response approaches.

[2] See National Wildlife Federation's *Scanning the Conservation Horizon* (2011) for a good discussion of adaptive capacity.

[3] *Front Ecol Environ* (2009) 7:362-370.

[4] Fortunately Mark and his colleagues have written a detailed report that defines how they use resilience, explains their analyses in a very transparent way, and has numerous examples: Anderson, M.G., M. Clark, and A. Olivero Sheldon. 2012. *Resilient Sites for Terrestrial Conservation in the Northeast and Mid-Atlantic Region*. The Nature Conservancy, Eastern Conservation Science. 168 pp. http://conserveonline.org/workspaces/ecs/documents/resilient-sites-for-terrestrial-conservation-1

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Special Issue: Resilience
Resilience: Make it Pop!

By Stephan Halloy, science coordinator, Southern Andes Conservation Program, The Nature Conservancy

Rebecca Benner's essay on resilience asks how we should identify this complex ecosystem property and whether we should protect it where it is strong or enhance it where it is weak. Let us first lay a quick foundation of understanding for dealing with these questions.

As homeostatic macro-organisms, communities over time maintain some level of constancy of measurable diagnostic features (species composition, abundance distribution, energy and material flows). This self-regulation is due to network interactions which lead to emergent system properties. It is not inherent to any of the elements of the system by itself.

Ecological resilience — the ability of such systems to bounce back to certain conditions after having been pushed away from them ("basins of attraction") — can only be inferred from proxies such as community structure or geological heterogeneity. Anderson et al. (2012) perform such analyses at a regional scale; however, as they state, they are estimating the capacity to adapt rather than resilience. Measuring resilience directly would require either destroying the system or "playing out the movie," i.e., sitting and waiting for things to happen (Lewin 1992, Gell-Mann 1994).

"It is worth taking into account the two extremes of 'why we care': the 'grandma's teapot' (museum) vs the 'plastic jug' machine)...Human nature and necessities means we will, somehow or other, always do both. Our challenge as scientists is to provide the information to balance society's choices."

It is also important to distinguish *resilience* (bouncing back to the same previous condition, e.g., Holling 1986, Naeem & Li 1997, Berkes et al. 2000) from *adaptation* (being able to change to track a changing landscape, e.g., IPCC 2007, Groves 2012), as both may in fact be to some degree contradictory (Kauffman 1991, 1993; Whitacre & Bender 2009).

Given external drivers such as drought, fire, pests, deforestation and urban development, system features will change. Given time, the system will either come back to some or all the original features or not, depending on the duration and intensity of the driver (Halloy & Barratt 2007). We know some of the return mechanisms, like succession. But for most practical systems, we don't know the response curve and thresholds — i.e., the point at which the system will shift from one state (or basin of attraction) to another…from a clear-water lake to a eutrophized turbid lake, for example.

A framework that addresses parts of the dilemmas suggested by Rebecca distinguishes four types of areas in the face of drivers such as climate change:

1. ***"No change" (or minor change) areas***. These are the areas identified by Anderson et al. (2012) or Killeen et al.'s refugia (Killeen et al. 2007, Weiser et al. 2007, Killeen & Solórzano 2008). They are in some ways the analogue of Peter Kareiva and Michelle

Marvier's "coldspots" in that they are less threatened yet need attention nonetheless. These are the obvious "protect as they are" choices.

2. ***"Total change" areas***, where future climates will have no current equivalent (Williams et al. 2007, Jarvis et al. 2008). These are the most threatened areas and will require high investment in rebuilding new functional ecosystems (for whatever purpose society decides).

3. ***"Equivalent areas" but in different places*** — i.e., areas with comparable geology, soils and climates in the future. In other words, site B, which today has a different climate and biota from site A, will in 2050 be an equivalent area to site A and could support species from site A. These areas require a combination of appropriate connectivity and possibly assisted migration and rebuilding.

4. ***"Corridors,"*** i.e., areas which allow the percolation of species from site A to B as conditions change. These areas require careful management across typically productive landscapes to facilitate species migrating through them.

A conservation portfolio with a whole-system view (Ward et al. 2011) should probably consider a balance of all these types of areas and intermediate variations.

It is worth taking into account the two extremes of "why we care": the "grandma's teapot" (museum) vs the "plastic jug" (machine) consideration. We make efforts to conserve pandas or quetzals mainly based on grandma's teapot considerations, regardless of function. We conserve watersheds to conserve function (i.e., the supply and quality of water) regardless of which species and communities ensure that function. We cannot choose to do only one or the other. Human nature and necessities means we will, somehow or other, always do both. Our challenge as scientists is to provide the information to balance society's choices. We should have museums, but we can't cover our cities only in museums. We need industry and housing, but our societies would not accept having only productive uses.

"Aquariologists understand that it takes effort to construct a balanced microcosm of water, fish, snails, microflora, vascular plants, and external inputs of light, water circulation, etc. But once a certain threshold is reached, the system "pops" — i.e. it stabilizes in a desired condition which requires a minimum of sustained inputs. Maybe there are important lessons here!"

Andean societies have long learned such balanced approaches. They learnt from past trial and error (playing the movie, but in the past) to develop sophisticated cultural and social institutions that use and manage connectivity and whole systems (verticality and reciprocity) rather than manage compartments (Halloy et al. 2005, Orlove 2005, Perez et al. 2010).

Large-scale, whole-system approaches such as those initiated by TNC`s Southern Andes conservation program in large watersheds (Lima, Peru; La Paz, Bolivia; Aconcagua and Maipo, Chile) provide opportunities to work with biodiversity, ecosystem function, social, cultural and economic interactions with a consideration of traditional knowledge. Such approaches cultivate the emergent properties of eco-social systems to allow them to bounce back (resilience) after disruptions as well as to adapt to change (Halloy et al. 2010).

Traditional conservation approaches have varied between intense command and control (Holling & Meffe 1996) and laissez-faire (Thoreau 1854, Walker & Salt 2007). Without entering into the philosophical debate, it is well to understand the consequences of adopting one or the other strategy and the degrees in between. Aquariologists understand that it takes effort to construct a balanced microcosm of water, fish, snails, microflora, vascular plants, and external inputs of light, water circulation, etc. But once a certain threshold is reached, the system "pops" — i.e., it stabilizes in a desired condition which requires a minimum of sustained inputs (Kelly 1994, Lehrer 2012). Maybe there are important lessons here!

Rebecca Benner's questions are dilemmas for most land stewards, many from before climate change was on the horizon: using standard consensus approaches, definitions, methods and measures are constant challenges which have a lot to do with human culture and fragmentation of science. **SC**

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Special Issue: Resilience

Numeracy as Opposed to Expert Opinion, and Making Resilience Real

By Peter Kareiva, chief scientist, The Nature Conservancy

Everyone loves resilience. NOAA's strategic plan focuses on "resilient communities." The PopTech! Conference just held a gathering on the theme of resilience that brought in thought leaders on banking, psychology, art, the environment, business and human development. We all want our children to be resilient. Is there anyone who does not aspire to it?

But what is resilience? And more specifically — what does it mean in the conservation context? To answer this question well, we need to embrace four principles:

1. ***There is no such thing as "resilience" in general***. Resilience must always be defined with respect to some specific attribute. For example, we might ask whether carbon fixation is resilient in a community, or biodiversity (number of species), or the supply of clean water. We could ask whether coral cover is resilient. The answers differ depending on the variable of interest. And that variable should always be measurable.

2. ***We need to distinguish between "resistance" and "resilience."*** *Resistance* is the extent to which an ecosystem (or any system) does NOT change when stressed. It can be measured as the % change per unit of stress (degrees of warming, meters of sea level rise, % loss of habitat, % reduction in flow rates, etc).

3. ***Resilience is the instantaneous rate at which a perturbation caused by a shock or stress decreases.*** It is quite simply:

"Resilience is quite easy to define precisely, and it is straightforward to measure. Unfortunately, the conservation community addresses resilience by relying too much on storytelling and consensus."

Let X = the deviation from a baseline in the chosen metric of interest (see #1 above).

Then X(0) is the deviation immediately following the shock or perturbation. X(t) is the deviation at time t. And the resilience index is: log X(t)/X(0)/t.

This is analogous to the dominant eigenvalue of the linearized matrix of component interactions, and has a rich history in dynamical systems theory. It is also practical — it describes the rate at which perturbations shrink.

In some case the perturbation will NOT decrease — that means the system has zero resilience.

And if one is lucky enough to have a time series of observation, one can simply fit a decay function to the data.

4. ***Unfortunately, the NGO community has gravitated towards expert opinion and non-quantitative assessments. We should reject consensus and expert opinion and instead turn towards data and predictions that can be falsified.***

We frequently ask field practitioners to assess recovery or resilience without gathering actual data. Big mistake. This is a recipe for no progress. If you do not believe me, consider the following:

I examined a large data set of published accounts of recovery or resilience following some major perturbations (oil spills, deforestation, mining, over-fishing, etc). I compared the judgments of the "expert" as recorded in the published papers with the actual recovery as measured by observed deviation from reference state. I did not use the above resilience index because, although it is scientifically more appropriate, I figured ecologists lean towards simpler metrics like "percentages" to inspire their expert opinions. In any event, as you can see below, the data for recovered versus not recovered are not different! That is crazy. It reveals the extent to which expert opinion is weakly disguised bias.

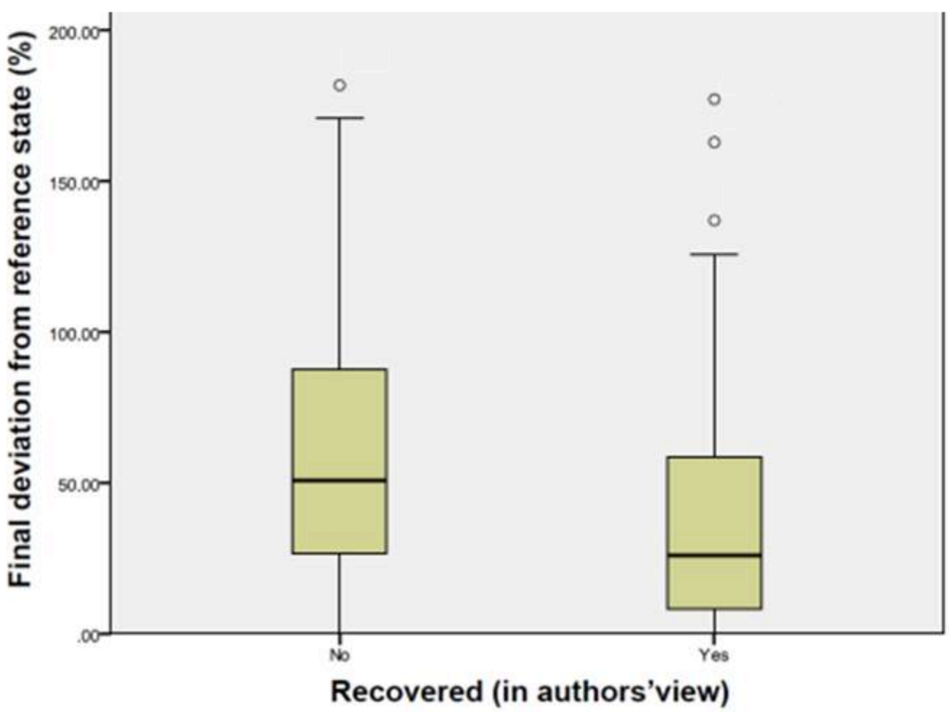

Figure 1. Box-and-whisker plot of deviations from baseline after time has elapsed for recovery. These depict the median and the 50% "box" of observations around that median – in others words, the box within which the central half of the observations fall. The whiskers represent the maximum and minimum, excluding the outliers. The outliers are defined as any data that are more than 1.5 times the interquartile range above or below the central box. The interquartile range is the distance between the bottom and top of the box.

Again, with huge sample sizes, *one could not detect significant differences in the final deviations from reference state between what the experts called "recovered" compared to what the experts called "not recovered*." It is my hypothesis that experts in conservation are strongly influenced by perception and attention biases, and that their conclusions about "resilient" or "not resilient" should be ignored. What we need are quantitative data in the form of #3 above.

Bottom line: In fact, "resilience" is quite easy to define precisely, and it is straightforward to measure. Unfortunately, the conservation community addresses resilience by relying too much on storytelling and consensus. That is sad. Resilience is something we are all in favor of — and is what we should be managing towards — but we can only do so if we measure it. **SC**

Special Issue: Resilience
Resilience Keeps Us on the Face of the Wave

By Rod Salm, senior advisor for science and strategies, Indo-Pacific Division, The Nature Conservancy

In the course of regularly grappling with resilience questions, many of which Rebecca Benner has posed, I have found three elements of ecosystem resilience that keep surfacing: *stress resistance, recovery and adaptation*. For coral reef resilience, we focus principally on the resistance and recovery elements in the face of thermal stress. We have yet to monitor and manage for adaptation. My answers to her questions will reflect that experience.

Why should we do resilience analyses — and do these need to do more than indicate where resilient places are? "Where" is important. It enables us to: (a) build resilient habitats into conservation planning as foundations for broader conservation planning; (b) help direct development along sustainable pathways by avoiding these resilient areas; and (c) focus management efforts on places with best potential for persistence.

Are "adaptive capacity" and "resilience" synonymous? Not fully. Resistance and recovery are central to the way we manage reefs, design MPA networks and deliver training. We monitor, measure and manage reefs to maintain status quo rather than to enhance acceptable levels of change — an arguably flawed approach in a rapidly changing world. However we define resilience, we should capture all three elements: resistance, recovery, adaptive capacity,

What do we do with resilience: build, enhance or protect it? We need to manage to restore, enhance and protect resilience. And we may well need to expand to proactive interventions that bolster the coastal protection functions of natural systems (as with oyster reefs) or change water chemistry to buffer the impacts of ocean acidification.

"In the marine world, we protect resilient areas because these provide sources of seed to repopulate the susceptible areas in times of stress. This approach surely would apply to all systems. These refugia form the core of our conservation investment, our blue chips."

Should we take similar approaches in marine, terrestrial and freshwater systems? I'm comfortable advocating that we do need to enhance or build and protect resilience in all systems. In the marine world, we protect resilient areas because these provide sources of seed to repopulate the susceptible areas in times of stress. This approach surely would apply to all systems. These refugia form the core of our conservation investment, our blue chips. And Rebecca is correct: We need to build out from these or embed them into broader management frameworks, as indeed we are doing through our "reef to ridges" approach that links reef and watershed management.

Is resilience a site-specific topic and not useful as a generalized framework? Our coral reef work shows that site specificity provides the nuance and the generalized framework still remains useful. We need a larger toolbox of case studies of applications to help us adapt our approaches at different sites.

We do need to accept that resilience is a little-understood concept in which new knowledge regularly changes the way we think. This poses the question Rebecca did not ask: *if there are so many unknowns, should we bother?* I am not at all put off that different efforts to model climate change impacts and vulnerability yield sometimes very different results, that the indicators of resilience are constantly being modified, and that analysis of these indicators can yield different rankings depending on how they are combined. Each new attempt and each iteration of an old one yields more information to help us hone our efforts.

For now, a good approach would seem to be:

- Capture the variability in resilience *among habitats* by including multiple replicates of all habitat types into conservation area networks and separating these widely apart to reduce the risk of any stress event taking out all protected examples of one habitat.
- Choose larger areas for protection over smaller to capture a) the variability of resilience *within habitats* and, at the same time, b) any uncertainty and acclimation in stress response. By investing time and effort in large areas, we are more likely to capture all pieces of the different patterns that make up the mosaic of how ecosystems will respond at the local, management-scale level to such large stress events as heat stress, rainfall changes, storms and acidification.
- Protect naturally resistant refugia.
- Develop better field indicators for identifying resilience. **SC**

15 Seconds of Fame
Jen Filipiak

Jen Filipiak is director of conservation science for The Nature Conservancy in Iowa. She's a cyclocross racer, archer and expert negotiator on behalf of watersheds local and global. Move over Katniss. Meet Jen.

CORN & BEANS: People rightly think of corn when they think of Iowa — a full 90% of the land is used for agriculture — but it's a lot more than corn and beans. My focus is on freshwater and whole systems.

Any Iowan will proudly tell you that we have the most fertile soils in the world — and that our water quality is declining. We need to improve yields while reducing environmental impacts and that's where water comes in — the Conservancy works on water quality and water flows.

Interview by Darci Palmquist. Know someone we should feature in this column? Please email her with comments or suggestions.

Image: Jen doing bike racing.

CYCLING: I got involved in racing when I moved to Iowa 5 years ago. The cycling community here is awesome. Bike racing is male dominated but here there's a lot of support for women's racing.

I do criterions (crits) — circuit racing. It's basically a 1-mile course you go round and round, very fast and very tight. To onlookers it might seem scary because we ride so close together that there's a high potential for collisions, but it doesn't happen often. I like it because it's exciting, fast and strategic. You have to work well with your team to win.

Fall, though, is cyclocross season — it's a cross between mountain biking and road racing. You have knobby, mountain-bike tires but on a road bike. Like a crit, the race is a short circuit that you ride over and over, but on grass, usually in a park, and there are always barriers that force you on and off the bike — you cross streams, go through mud, etc. Cyclocross is probably the most spectator friendly bike race!

WINNING: Yeah, I ride to win. I'm competitive by nature. I usually finish in the top third of my category, but it all depends on the race, and who else shows up.

"THE HUNGER GAMES": My dad is a bow hunter — he uses a bow and arrow to hunt deer. To do that you have to understand ecology and animal behavior, so that inspired my interest in conservation. Growing up in the Chicago suburbs, vacations were always to rural areas to get out of the city. My mom is also a competitive archer and my sister and I were raised with archery. I don't hunt, but I can shoot an arrow.

COOL CONSERVATION: What I think is most exciting, but also incredibly difficult, is striving for integrated management of big watersheds, right in line with TNC's increasing whole-systems focus.

For instance, the Mississippi River touches 10 states, so every decision impacts somewhere else. We need to get a handle on management of whole watersheds, not just pieces. In Iowa, we've had major floods every year for the past few years. We're trying to work collaboratively with competing water interests in the Cedar River Basin, a 12,000-square-mile watershed. It's huge for us, but small from a global perspective.

Integrated river management is not just a TNC issue. Everyone who works on rivers is thinking about this. The Danube in Europe has achieved some level of integrated management. But every basin is different and depends on the politics. Competing interests for water has led to the Colorado River no longer flowing into Mexico — we simply must figure out how to manage these resources together.

LOVE MY JOB: What gives me the greatest satisfaction is getting people to collaborate, to find common ground and achieve something we couldn't have done on our own.

It's kind of like habitat restoration — say you're cutting down trees to open up an overgrown savanna. It looks terrible at first, but you see the sunlight dappling through and you know it's going to respond. Next spring, the wildflowers start showing up again. You get to watch what happens, how it changes. If you're waiting for the end goal, you'll never be happy. But if you view it as a process, it's so rewarding. **SC**

Drinking from the Fire Hose

A quick monthly roundup of interesting articles, websites and other experiences collected by your editor. Send your suggestions for future roundups to rlalasz@tnc.org.

1) Women as Academic Authors, 1665-2010 (*Chronicle of Higher Education*): The Eigenfactor Project at the University of Washington reviewed about 2 million articles in JSTOR's archive to come up with the first comprehensive historic analysis of gender in scholarly authorship (lots of fascinating bubble graphs broken out by discipline). Among the takeaways in the accompanying analysis: Proportions of female first-authors and authors overall are rising, but not for last-position female authors, especially in the bio sciences — a sign women still aren't in senior scholar, lab-supervisory positions.

2) A Real-Life Indiana Jones (*New York Times*/Green): Who's cooler: Darwin or Wallace? For biodiversity conservationists, it's Wallace hands-down, writes TNC's Craig Leisher. One tough dude.

3) Why Climate Disasters Might Not Boost Public Engagement on Climate Change (Dot Earth): Simply put, argues George Marshall, they *reinforce* social norms, networks and worldviews. Fascinating and challenging (to say the least) for climate comms.

4) **Scientists Eat Crow on Geoengineering Test. Me, Too. (Climate Central):** While policymakers dither about climate change, impatient types like businessman Russ George are hacking the planet with DIY geoengineering — in George's case, dumping 100 metric tons of iron sulfate into the Pacific off western Canada, which led to an algae bloom that could (if large enough) suck CO2 from the atmosphere and theoretically cool the planet. Scientists didn't think anybody would be fool enough to try it, writes Michael D. Lemonick. It also violated two UN conventions. Gee.

5) Delusions of Danger (Slate): Keith Kloor, one of my favorite science writers, gets the can of whoop-butt out on the food movement for what he calls its un-science-based demonization of GMOs — which Kloor says stems from environmentalism's refusal to evolve from its 1970s, Barry Commoner-worldview that "nature knows best." Hottest buttons Kloor pushes here: Accusing Michael Pollan and Mark Bittman of using anxiety about GMOs to attach Big Ag, regardless of the science.

6) Willing or Unwilling to Share Primary Biodiversity Data: Results and Implications of an International Survey (*Conservation Letters*): Do conservation scientists need a time out? While "biodiversity science and conservation increasingly depend on the sharing and integration of large amounts of data," more than 60% of respondents to this survey were unwilling to share primary data before publishing.

7) How Not to Spend Your Whole Day on Facebook (Big Think): Or on any other thing you use to procrastinate with — Charles Duhigg, author of *The Power of Habit*, says science can help. (Hint: It involves doing it.) SC

Science Short
What You Can't See Can Kill You

Thomas, M.K., C.T. Kremer, C.A. Klausmeier, & E. Litchman. 2012. A global pattern of thermal adaptation in marine phytoplankton. *Science* DOI: 10.1126/science.1224836

Coral bleaching, increasing storms and the loss of the polar bear — many of the impacts of climate change are already vivid in our minds. But what about the impacts still invisible to the naked eye, lurching in the background and ready to strike — such as the direct effects that rising ocean temperatures have on phytoplankton growth? Phytoplankton are the most important part of the ocean food web. They account for one-half of all photosynthetic activity on Earth, making them responsible for much of the oxygen present in the Earth's atmosphere — one-half of the total amount produced by all plant life. And they're food to a range of marine species, from soft corals to small ocean fish (herring, sardine, menhaden) to the largest fish on the planet (whale shark). Thomas et al. find that a warming ocean will alter the productivity and composition of marine phytoplankton communities, particularly tropical communities, leading to phytoplankton biodiversity declines and shifts in species ranges. The authors suggest that previous predictions for phytoplankton, focused mainly on indirect effects, may have underestimated the impacts that warming will have on these creatures — which also means the impacts climate will have on our air and food. Our chance of being truly resilient to climate change will depend on our understanding of these and other invisible ocean impacts. **SC**

— **Vera Agostini**, senior scientist, Global Marine Team, The Nature Conservancy

New Conservancy Publications

Conservancy-affiliated authors highlighted in bold.

Please send new citations and the PDF (when possible) to: pkareiva@tnc.org and rlalasz@tnc.org. Please include "Chronicles Citation" in your subject line so we don't miss it.

Some references also contain a link to the paper's abstract and/or a downloadable PDF of the paper. When open source or permitted by journal publisher, these PDFs are being stored on the Conservation Gateway, which also is keeping a running list of Conservancy authored science publications since 2009.

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