M/C Journal, Vol. 16, No. 5 (2013) - 'resilient'

Building Resilient Communities

http://journal.media-culture.org.au/index.php/mcjournal/article/view/716

Karey Harrison

This paper will compare the metaphoric structuring of the ecological concept of resilience—with its roots in Holling's 1973 paper; with psychological concepts of resilience which followed from research —such as Werner, Bierman, and French and Garmezy and Streitman) published in the early 1970s.

This metaphoric analysis will expose the difference between complex adaptive systems models of resilience in ecology and studies related to resilience in relation to climate change; compared with the individualism of linear equilibrium models of resilience which have dominated discussions of resilience in psychology and economics. By examining the ontological commitments of these competing metaphors, I will show that the individualistic concept of resilience which dominates psychological discussions of resilience is incompatible with the ontological commitments of ecological concepts of resilience.

Because the ontological commitments of the concepts of ecological resilience on the one hand, and psychological resilience on the other, are so at odds with one another, it is important to be clear which concept of resilience is being evaluated for its adequacy as a concept.

Having clearly distinguished these competing metaphors and their ontological commitments, this paper will show that it is the complex adaptive systems model of resilience from ecology, not the individualist concept of psychological resilience, that has been utilised by both the academic discussions of adaptation to climate change, and the operationalisation of the concept of resilience by social movements like the permaculture, ecovillage, and Transition Towns movements.

Ontological Metaphors

My analysis of ontological metaphors draws on insights from Kuhn's (114) account of gestalt perception in scientific paradigm shifts; the centrality of the role of concrete analogies in scientific reasoning (Masterman 77); and the theorisation of ontological metaphors in cognitive linguistics (Gärdenfors).

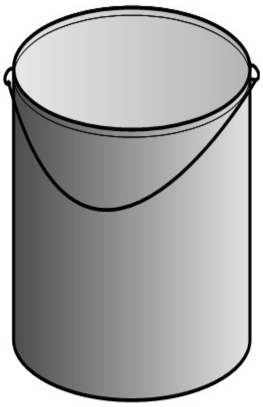

Figure 1: Object

Ontological commitments reflect the shared beliefs within a community about the *sorts of things that exist*. Our beliefs about what exists are shaped by our sensory and motor interactions with objects in the physical world. Physical objects have boundaries and surfaces that separate the object from not-the-object. Objects have insides and outsides, and can be described in terms of more-or-less fixed and stable "objective" properties. A prototypical example of an "object" is a "container", like the example shown in Figure 1. Ontological metaphors allow us to conceive of "things" which are *not* objects *as if* they were objects by picking "out parts of our experience and treat them as [if they were] discrete entities or substances of a uniform kind" (Lakoff and Johnson 25).

We use ontological metaphors when we imagine a boundary around a collection of things, such as the members of a team or trees in a forest, and conceive of them as being *in* a container (Langacker

191–97). We can then think of "things" like a team or forest *as if* they were a single entity. We can also understand processes and activities *as if* they were things with boundaries. Whether or not we characterise some aspect of our experience as a noun (a bounded entity) or as a verb (a process that occurs over time) is not determined by the nature of things in themselves, but by our understanding and interpretation of our experience (Langacker 233).

In this paper I employ a technique that involves examining the details of "concrete images" from the source domains for metaphors employed in the social sciences to expose for analysis their ontological commitments (Harrison, "Politics" 215; Harrison, "Economics" 7). By examining the ontological metaphors that structure the resilience literature I will show how different conceptions of resilience reflect different beliefs and commitments about the sorts of "things" there are in the world, and hence how we can study and understand these "things."

Engineering Metaphors

In his discussion of engineering resilience, Holling ("Engineering Vs. Ecological" 33) argues that this conception is the "foundation for *economic* theory", and defined in terms of "resistance to disturbance and the speed of return to the equilibrium" or steady state of the system. Whereas Holling takes his original example of the use of the engineering concept of resilience from economics, Pendall, Foster, & Cowell (72), and Martin-Breen and Anderies (6) identify it as the concept of resilience that dominates the field of *psychology.* They take the *stress loading of bridges* to be the engineering source for the metaphor.

Figure 2: Pogo stick animation (Source: Blacklemon 67, CC http://en.wikipedia.org/wiki/File:Pogoanim.gif).

In order to understand this metaphor, we need to examine the characteristics of the source domain for the metaphor. A bridge can be "under tension, compression or both forces at the same time [and] experiences what engineers define as *stress*" (Matthews 3). In order to resist these forces, bridges need to be constructed of material which "behave much like a *spring*" that "strains elastically (deforms temporarily and returns to its original shape after a load has been removed) under a given stress" (Gordon 52; cited in Matthews). The pogostick shown in Figure 2 illustrates how a spring returns to its original size and configuration once the load or stress is removed.

WGBH Educational Foundation provides links to simple diagrams that illustrate the different stresses the three main designs of bridges are subject to, and if you compare Computers & Engineering's with Gibbs and Bourne's harmonic spring animation you can see how both a bridge under live load and the pogostick in Figure 2 oscillate just like an harmonic spring. Subject to the elastic limits of the material, the deformation of a spring is proportional to the stress or load applied. According to the "modern theory of elasticity [...] it [is] possible to deduce the relation between strain and stress for complex objects *in terms of intrinsic properties of the materials it is made of*" ("Hooke's Law").

When psychological resilience is characterised in terms of "*properties of individuals* [that] are identified in isolation" (Martin-Breen and Anderies 12); and in terms of "behaviours and *attributes [of individuals*] that allow people to get along with one another and to succeed socially" (Pendall, Foster, and Cowell 72), they are reflecting this engineering focus on the properties of materials. Martin-Breen and Anderies (42) argue that "the Engineering Resilience framework" has been informed by ontological metaphors which treat "an ecosystem, person, city, government, bridge, [or] society" as if it were an object—"a unified whole". Because this concept of resilience treats individuals as "objects," it leads researchers to look for the properties or characteristics of the "materials" which individuals are "made of", which are either elastic and allow them to "bounce" or "spring" back after stress; or are fragile and brittle and break under load.

Similarly, the Designers Institute (DINZ), in its conference on "Our brittle society," shows it is following the engineering resilience approach when it conceives of a city or society as an object which is made of materials which are either "strong and flexible" or "brittle and fragile".

While Holling characterises economic theory in terms of this engineering metaphor, it is in fact chemistry and the *kinetic theory of gases* that provides the source domain for the ontological metaphor which structures both static and dynamic equilibrium models within neo-classical *economics* (Smith and Foley; Mirowski).

However, while springs are usually made out of metals, they can be made out of any "material [that] has the required combination of rigidity and elasticity," such as plastic, and even wood (in a bow) ("Spring (device)"). Gas under pressure turns out to behave the same as other springs or elastic materials do under load. Because both the economic metaphor based on equilibrium theory of gases and the engineering analysis of bridges under load can both be subsumed under spring theory, we can treat both the economic (gas) metaphor and the engineering (bridge) metaphor as minor variations of a single overarching (spring) metaphor.

Complex Systems Metaphors

Holling ("Resilience & Stability" 13–15) critiques equilibrium models, arguing that non-deterministic, complex, non-equilibrium and multi-equilibrium ecological systems do not satisfy the conditions for application of equilibrium models. Holling argues that unlike the single equilibrium modelled by engineering resilience, complex adaptive systems (CAS) may have multi or no equilibrium states, and be non-linear and non-deterministic.

Walker and Salt follow Holling by calling for recognition of the "dynamic complexity of the real world" (8), and that "these [real world] systems are *complex adaptive systems*" (11). Martin-Breen and Anderies (7) identify the key difference between "systems" and "complex adaptive systems" resilience as adaptive capacity, which like Walker and Salt (xiii), they define as the capacity to maintain function, even if system structures change or fail.

The "engineering" concept of resilience focuses on the (elastic) properties of materials and uses language associated with elastic springs. This "spring" metaphor emphasises the property of individual components.

In contrast, ecological concepts of resilience examine *interactions* between elements, and the state of the system in a multi-dimensional phase space. This systems approach shows that the complex behaviour of a system depends at least as much on the relationships between elements. These relationships can lead to "emergent" properties which cannot be reduced to the properties of the parts of the system.

To explain these relationships and connections, ecologists and climate scientists use language and images associated with landscapes such as 2-D cross-sections and 3-D topology (Holling, "Resilience & Stability" 20; Pendall, Foster, and Cowell 74).

Figure 3 is based on an image used by Walker, Holling, Carpenter and Kinzig (fig. 1b) to represent possible states of ecological systems. The "basins" in the image rely on our understanding of gravitational forces operating in a 3-D space to model "equilibrium" states in which the system, like the "ball" in the "basin", will tend to settle.

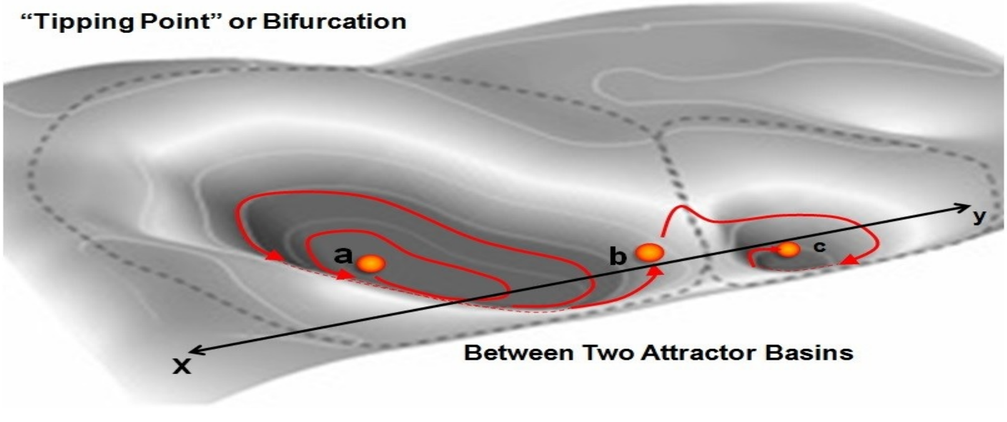

Figure 3: (based on Langston; in Walker et al. fig. 1b) – Tipping Point Bifurcation

Wasdell ("Feedback" fig. 4) adapted this image to represent possible climate states and explain the concept of "tipping points" in complex systems. I have added the red balls (*a*, *b*, and *c* to replace the one black ball (b) in the original which represented the state of the system), the red lines which indicate the path of the ball/system, and the black x-y axis, in order to discuss the image.

Wasdell ("Feedback Dynamics" slide 22) takes the left basin to represents "the variable, near-equilibrium, but contained dynamics of the [current] glacial/interglacial period". As a result of rising GHG levels, the climate system absorbs more energy (mostly as heat). This energy can force the system into a different, hotter, state, less amenable to life as we know it. This is shown in Figure 3 by the system (represented as the red ball a) rising up the left basin (point *b*). From the perspective of the gravitational representation in Figure 3, the extra energy in the basin operates like the rotation in a Gravitron amusement ride, where centrifugal force pushes riders up the sides of the ride.

If there is enough energy added to the climate system it could rise up and jump over the ridge/tipping point separating the current climate state into the "hot earth" basin shown on the right. Once the system falls into the right basin, it may be stuck near point *c*, and due to *reinforcing feedbacks* have difficulty escaping this new "equilibrium" state.

Figure 4 represents a 2-D cross-section of the 3-D landscape shown in Figure 3. This cross-section shows how rising temperature and greenhouse gas (GHG) concentrations in a multi-equilibrium climate topology can lead to the climate crossing a tipping point and shifting from state *a* to state *c*.

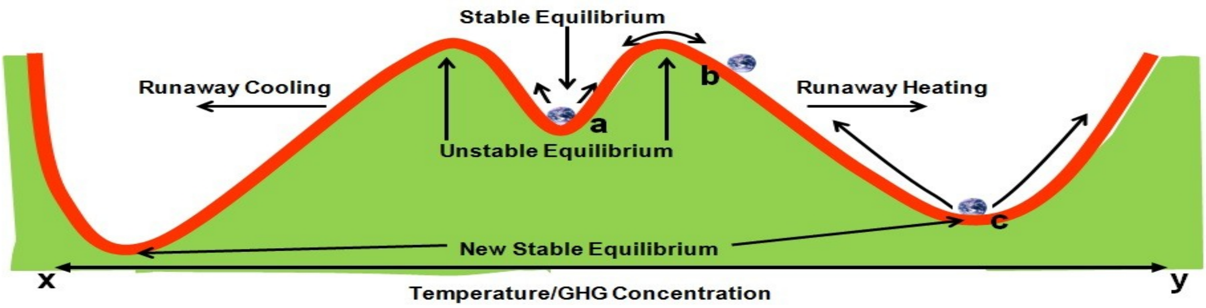

Figure 4: Topographic cross-section of possible climate states (derived from Wasdell, "Feedback" 26 CC).

As Holling ("Resilience & Stability") warns, a less "desirable" state, such as population collapse or extinction, may be more "resilient", in the engineering sense, than a more desirable state. Wasdell ("Feedback Dynamics" slide 22) warns that the climate forcing as a result of human induced GHG emissions is in fact pushing the system "far away from equilibrium, passed the tipping point, and into the hot-earth scenario". In previous episodes of extreme radiative forcing in the past, this "disturbance has then been amplified by powerful feedback dynamics not active in the near-equilibrium state [… and] have typically resulted in the loss of about 90% of life on earth."

An essential element of system dynamics is the existence of (delayed) *reinforcing* and *balancing* causal *feedback* loops, such as the ones illustrated in Figure 5.

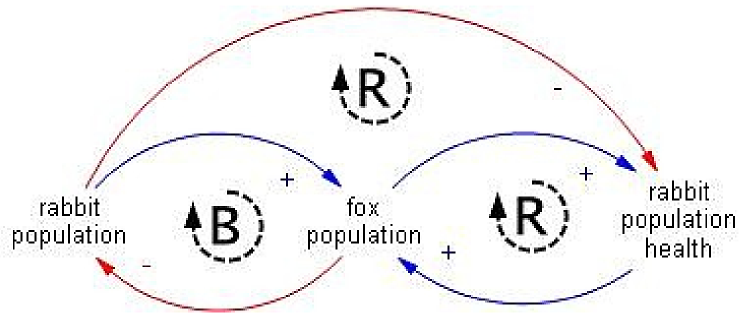

Figure 5: Pre/Predator model (Bellinger CC-BY-SA)

In the case of Figure 5, the *feedback loops* illustrate the relationship between rabbit population increasing, then foxes feeding on the rabbits, keeping the rabbit population within the carrying capacity of the ecosystem. Fox predation prevents rabbit over-population and consequent starvation of rabbits.

The reciprocal interaction of the elements of a system leads to unpredictable nonlinearity in "even seemingly simple systems" ("System Dynamics"). The climate system is subject to both positive and negative feedback loops. If the area of ice cover increases, more heat is reflected back into space, creating a positive feedback loop, reinforcing cooling. Whereas, as the arctic ice melts, as it is doing at present (Barber), heat previously reflected back into space is absorbed by now exposed water, increasing the rate of warming.

> Where *negative feedback* (system damping) dominates, the cup-shaped equilibrium is stable and system behaviour returns to base when subject to disturbance. [...]The impact of extreme events, however, indicates limits to the stable equilibrium. At one point *cooling feedback loops* overwhelmed the homeostasis, precipitating the "snowball earth" effect. […] Massive release of CO2 as a result of major volcanic activity […] set off *positive feedback loops*, precipitating runaway global warming and eliminating most life forms at the end of the Permian period. (Wasdell, "Topological")

Martin-Breen and Anderies (53–54), following Walker and Salt, identify four key factors for systems (ecological) resilience in nonlinear, non-deterministic (complex adaptive) systems: regulatory (balancing) feedback mechanisms, where increase in one element is kept in check by another element;

> modularity, where failure in one part of the system will not cascade into total systems failure; functional redundancy, where more than one element performs every essential function; and, self-organising capacity, rather than central control ensures the system continues without the need for "leadership".

Transition Towns as a Resilience Movement

The Transition Town (TT) movement draws on systems modelling of both climate change and of *Limits to Growth* (Meadows et al.). TT takes seriously *Limits to Growth* modelling that showed that without constraints in population and consumption the world faces systems collapse by the middle of this century. It recommends community action to build as much capacity as possible to "maintain existence of function"—Holling's ("Engineering vs. Ecological" 33) definition of ecological resilience—in the face of failing economic, political and environmental systems.

The Transition Network provides a template for communities to follow to "rebuild resilience and reduce CO2 emissions". Rob Hopkins, the movements founder, explicitly identifies ecological resilience as its central concept (*Transition Handbook* 6). The idea for the movement grew out of a project by (2nd year students) completed for Hopkins at the Kinsale Further Education College. According to Hopkins ("Kinsale"), this project was inspired by Holmgren's *Permaculture principles* and Heinberg's book on adapting to life after peak oil.

Permaculture (permanent agriculture) is a design system for creating agricultural systems modelled on the diversity, stability, and *resilience* of natural ecosystems (Mollison ix; Holmgren xix). Permaculture draws its scientific foundations from systems ecology (Holmgren xxv). Following CAS theory, Mollison (33) defines stability as "self-regulation", rather than "climax" or a single equilibrium state, and recommends "diversity of *beneficial functional connections*" (32) rather than diversity of isolated elements. Permaculture understands resilience in the ecological, rather than the engineering sense.

The Transition Handbook (17) "explores the issues of peak oil and climate change, and how when looked at together, we need to be focusing on the rebuilding of resilience as well as cutting carbon emissions. It argues that the focus of our lives will become increasingly local and small scale as we come to terms with the real implications of the energy crisis we are heading into."

The Transition Towns movement incorporate each of the four systems resilience factors, listed at the end of the previous section, into its template for building resilient communities (Hopkins, *Transition Handbook* 55–6). Many of its recommendations build "modularity" and "self-organising", such as encouraging communities to build "local food systems, [and] local investment models". Hopkins argues that in a "more localised system" feedback loops are tighter, and the "results of our actions are more obvious". TT training exercises include awareness raising for sensitivity to networks of (actual or potential) ecological, social and economic relationships (Hopkins, *Transition Handbook* 60–1). TT promotes diversity of local production and economic activities in order to increase "diversity of functions" and "diversity of responses to challenges."

Heinberg (8) wrote the forward to the 2008 edition of the Transition Handbook, after speaking at a TotnesTransition Town meeting. Heinberg is now a senior fellow at the Post Carbon Institute (PCI), which was established in 2003 to "provide […] the resources needed to understand and respond to the interrelated economic, energy, environmental, and equity crises that define the 21st century [… in] a world of resilient communities and re-localized economies that thrive *within ecological bounds*" (PCI, "About"), of the sort envisioned by the *Limits to Growth* model discussed in the previous section. Given the overlapping goals of PCI and Transition Towns, it is not surprising that Rob Hopkins is now a Fellow of PCI and regular contributor to *Resilience*, and there are close ties between the two organisations.

Resilience, which until 2012 was published as the *Energy Bulletin*, is run by the Post Carbon Institute (PCI). Like Transition Towns, *Resilience* aims to build "community resilience in a world of multiple emerging challenges: the decline of cheap energy, the depletion of critical resources like water, complex environmental crises like climate change and biodiversity loss, and the social and economic issues which are linked to these. […] It has [its] roots in systems theory" (PCI, "About Resilience"). *Resilience*.org says it follows the interpretation of Resilience Alliance (RA) Program Director Brian Walker and science writer David Salt's (xiii) ecological definition of resilience as "the capacity of a system to absorb disturbance and still retain its basic function and structure."

Conclusion

This paper has analysed the ontological metaphors structuring competing conceptions of resilience. The engineering resilience metaphor dominates in psychological resilience research, but is not adequate for understanding resilience in complex adaptive systems. Ecological resilience, on the other hand, dominates in environmental and climate change research, and is the model of resilience that has been incorporated into the global permaculture and Transition Towns movements.

References

2nd year students. *Kinsale 2021: An Energy Descent Action Plan*. Kinsale, Cork, Ireland: Kinsale Further Education College, 2005. 16 Aug. 2013 <http://transitionculture.org/wp-content/uploads/KinsaleEnergyDescentActionPlan.pdf>.

Barber, Elizabeth. "Arctic Ice Continues to Thin, and Thin, European Satellite Reveals." *Christian Science Monitor* 11 Sep. 2013. 25 Sep. 2013 <http://www.csmonitor.com/Environment/2013/0911/Arctic-ice-continues-to-thin-and-thin-European-satellite-reveals>.

Bellinger, Gene. "Prey/Predator Model." *SystemsWiki* 23 Nov. 2009. 16 Aug. 2013 <http://systemswiki.org/index.php?title=Prey/Predator_Model>.

Blacklemon67. "Pogo Animation." *Wikipedia* 2007. 24 Sep. 2013 <http://en.wikipedia.org/wiki/File:Pogoanim.gif>.

Computers & Engineering. *Bridge Trucks Animated Stress Plot 1*. 2003. GIF file. SAP2000 Bridge Design. <http://www.comp-engineering.com/announce/bridge/demo/truck_1.gif>.

DINZ. "Resilience Engineering: 'Our Brittle Society' - The Sustainability Society - May 18th 2012." *The Designers Institute*. 2013. 11 Aug. 2013 <http://www.dinz.org.nz/Events/2012/May/47965>.

Gärdenfors, Peter. "Cognitive Semantics and Image Schemas with Embodied Forces." *Embodiment in Cognition and Culture*. Ed. John Michael Krois et al. John Benjamins Publishing, 2007. 57–76. 8 Nov. 2012 <http://oddelki.ff.uni-mb.si/filozofija/files/Festschrift/Dunjas_festschrift/gardenfors.pdf>.

Garmezy, N, and S Streitman. "Children at Risk: The Search for the Antecedents of Schizophrenia. Part I. Conceptual Models and Research Methods." *Schizophrenia Bulletin* 8 (1974): 14–90. *NCBI PubMed* 14 Aug. 2013 <http://schizophreniabulletin.oxfordjournals.org/content/1/8/14.full.pdf>.

Gibbs, Keith, and John Bourne. "The Helical Spring." *Schoolphysics* 2013. 15 Aug. 2013 <http://www.schoolphysics.co.uk/animations/Helical_spring_shm/index.html>.

Gordon, James Edward. *Structures: Or, Why Things Don't Fall Down*. London: Plenum Press, 1978.

Harrison, Karey. "Image Schemas and Political Ontology." *Communication, Cognition and Media: Political and Economic Discourse*. Ed. Augusto Soares da Silva et al. Portugal: Aletheia, forthcoming.

———. "Ontological Commitments of Ethics and Economics." *Economic Thought* 2.1 (2013): 1–19. 23 Apr. 2013 <http://et.worldeconomicsassociation.org/article/view/64>.

Heinberg, Richard. *Powerdown: Options and Actions for a Post-carbon World*. New Society Publishers, 2004.

Holling, Crawford Stanley. "Engineering Resilience versus Ecological Resilience." *Engineering within Ecological Constraints*. Ed. Peter Schulze. Washington, DC: National Academy Press, 1996. 31–44. 11 Aug. 2013 <http://www.nap.edu/openbook.php?record_id=4919&page=31>.

———. "Resilience and Stability of Ecological Systems." *Annual Review of Ecology and Systematics* 4.1 (1973): 1–23. 11 Aug. 2013 <http://webarchive.iiasa.ac.at/Admin/PUB/Documents/RP-73-003.pdf>.

Holmgren, David. *Permaculture: Principles & Pathways beyond Sustainability*. Holmgren Design Services, 2002.

Hopkins, Rob. "Kinsale Energy Descent Action Plan (2005)." *Transition Culture: an Evolving Exploration into the Head, Heart and Hands of Energy Descent*. n.d. 16 Aug. 2013 <http://transitionculture.org/essential-info/pdf-downloads/kinsale-energy-descent-action-plan-2005/>.

———. *The Transition Handbook: From Oil Dependency to Local Resilience*. Green Books, 2008. Print.

———. *The Transition Handbook: From Oil Dependency to Local Resilience*. Free edit version. <http://www.appropedia.org/Category:The_Transition_Handbook: Appropedia.org> 2010. 16 Aug. 2010 <http://www.cs.toronto.edu/~sme/CSC2600/transition-handbook.pdf>.

Kuhn, Thomas. *The Structure of Scientific Revolutions*. 2nd ed. University of Chicago Press, 1962.

Lakoff, George, and Mark Johnson. *Metaphors We Live By*. University of Chicago Press, 1980.

Langacker, Ronald W. *Foundations of Cognitive Grammar: Theoretical Prerequisites*. Vol. 1. Stanford University Press, 1987.

Langston, Art. *"Tipping Point" or Bifurcation Between Two Attractor Basins*. 2004. 25 Sep. 2013. <http://www.ecologyandsociety.org/vol9/iss2/art5/figure1.html>.

Martin-Breen, Patrick, and J. Marty Anderies. *Resilience: A Literature Review*. Rockefeller Foundation, 2011. 8 Aug. 2013 <http://www.rockefellerfoundation.org/blog/resilience-literature-review>.

Masterman, Margaret. "The Nature of a Paradigm." *Criticism and the Growth of Knowledge*. Eds. Imre Lakatos & Alan Musgrave. Cambridge University Press, 1970. 59–89.

Matthews, Theresa. "The Physics of Bridges." *Yale-New Haven Teachers Institute*. 2013. 14 Aug. 2013 <http://www.yale.edu/ynhti/curriculum/units/2001/5/01.05.08.x.html>.

Meadows, Donella H. et al. *The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind*. Universe Books, 1972.

Mirowski, Philip. "From Mandelbrot to Chaos in Economic Theory." *Southern Economic Journal* 57.2 (1990): 289–307.

Mollison, Bill. *Permaculture: A Designers' Manual*. Tagari Publications, 1988.

PCI. "About." *Post Carbon Institute*. 16 July 2012. 16 Aug. 2013 <http://www.postcarbon.org/about/>.

———. "About Resilience.org." *Resilience* 16 July 2012. 16 Aug. 2013 <http://www.resilience.org/about>.

Pendall, Rolf, Kathryn A. Foster, and Margaret Cowell. "Resilience and Regions: Building Understanding of the Metaphor." *Cambridge Journal of Regions, Economy and Society* 3.1 (2010): 71–84. 4 Aug. 2013 <http://cjres.oxfordjournals.org/content/3/1/71>.

RA. "About RA." *Resilience Alliance* 2013. 16 Aug. 2013 <http://www.resalliance.org/index.php/about_ra>.

Smith, Eric, and Duncan K. Foley. "Classical Thermodynamics and Economic General Equilibrium Theory." *Journal of Economic Dynamics and Control* 32.1 (2008): 7–65.

Transition Network. "About Transition Network." *Transition Network*. 2012. 16 Aug. 2013 <http://www.transitionnetwork.org/about>.

Walker, B. H., and David Salt. *Resilience Thinking: Sustaining Ecosystems and People in a Changing World*. Island Press, 2006.

Walker, Brian et al. "Resilience, Adaptability and Transformability in Social–Ecological Systems." *Ecology and Society* 9.2 (2004): 5.

Wasdell, David. "A Topological Approach." *The Feedback Crisis in Climate Change: The Meridian Report*. n.d. 16 Aug. 2013 <http://www.meridian.org.uk/Resources/Global%20Dynamics/Feedback%20Crisis/frameset1.htm?p=3>.

———. "Beyond the Tipping Point: Positive Feedback and the Acceleration of Climate Change." The Foundation for the Future, Humanity 3000 Workshop. Seattle, 2006. <http://www.meridian.org.uk/_PDFs/BeyondTippingPoint.pdf>.

———. "Feedback Dynamics and the Acceleration of Climate Change." Winterthur, 2008. 16 Aug. 2013 <http://www.crisis-forum.org.uk/events/Workshop1/Workshop1_presentations/wasdellpictures/wasdell_clubofrome.php>.

Werner, Emmy E., Jessie M. Bierman, and Fern E. French. *The Children of Kauai: A Longitudinal Study from the Prenatal Period to Age Ten*. University of Hawaii Press, 1971.

WGBH. "Bridge Basics." *Building Big*. 2001. 14 Aug. 2013 <http://www.pbs.org/wgbh/buildingbig/bridge/basics.html>.

Wikipedia contributors. "Gravitron." *Wikipedia, the Free Encyclopedia* 20 Sep. 2013. 25 Sep. 2013 <http://en.wikipedia.org/wiki/Gravitron>.

———. "Hooke's Law." *Wikipedia, the Free Encyclopedia* 8 Aug. 2013. 15 Aug. 2013 <http://en.wikipedia.org/wiki/Hooke%27s_law>.

———. "Spring (device)." *Wikipedia, the Free Encyclopedia* 9 Aug. 2013. 24 Sep. 2013 <http://en.wikipedia.org/wiki/Spring_(device)>.

———. "System Dynamics." *Wikipedia, the Free Encyclopedia* 9 Aug. 2013. 13 Aug. 2013 <http://en.wikipedia.org/wiki/System_dynamics>.