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SYRACUSE CENTER OF EXCELLENCE IN ENVIRONMENTAL AND ENERGY SYSTEMS

Working Paper:
Resilience of Communities—Sustainability, Environment and Energy

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Measuring Resilience and Adaptive Capacity for Local Populations

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Positing Resiliency as it Relates to the Environment/Ecosystem

From The Resilience Alliance (resilience.org):

Ecosystem resilience is the capacity of an ecosystem to tolerate disturbance without collapsing into a qualitatively different state that is controlled by a different set of processes. A resilient ecosystem can withstand shocks and rebuild itself when necessary. Resilience in social systems has the added capacity of humans to anticipate and plan for the future. Humans are part of the natural world. We depend on ecological systems for our survival and we continuously impact the ecosystems in which we live from the local to global scale. Resilience is a property of these linked social-ecological systems.

"Resilience" as applied to ecosystems, or to integrated systems of people and the natural environment, has three defining characteristics:

- *The amount of change the system can undergo and still retain the same controls on function and structure*
- *The degree to which the system is capable of self-organization*
- *The ability to build and increase the capacity for learning and adaptation*

The resilience of social-ecological systems depends largely on underlying, slowly changing variables such as climate, land use, nutrient stocks, human values and policies. Resilience can be degraded by a large variety of factors including:

- *Loss of biodiversity*
- *Toxic pollution*
- *Inflexible, closed institutions*
- *Perverse subsidies that encourage unsustainable use of resources*
- *A focus on production and increased efficiencies that leads to a loss of redundancy*

Natural systems are inherently resilient but just as their capacity to cope with disturbance can be degraded, so can it be enhanced. The key to resilience in social-ecological systems is diversity. Biodiversity plays a crucial role by providing functional redundancy. For example, in a grassland ecosystem, several different species will commonly perform nitrogen fixation, but each species may respond differently to climatic events, thus ensuring that even though some species may be lost, the process of nitrogen fixation within the grassland ecosystem will continue. Similarly, when the management of a resource is shared by a diverse group of stakeholders (e.g., local resource users, research scientists, community members with traditional knowledge, government representatives, etc.), decision-making is better informed and more options exist for testing policies. Active adaptive management whereby management actions are designed as experiments encourages learning and novelty, thus increasing resilience in social-ecological systems.

Abstract

Attributes & Social Structures of Resilient Communities

Resilient communities should exhibit the following sustainability attributes (not comprehensive), many of which add a new dimension requiring different approaches to security:

- Close knit, physically dense communities in order to decrease energy consumption
- Access to clean water
- Community gardens/access to arable land
- Walking distance to work, schools, hospitals, food and public transportation
- Access to energy efficient housing (or cooperative housing), made from renewable, local resources, powered by renewable, distributed energy
- A cooperative grocery for those things that cannot be grown, with availability of petroleum-free packaging
- Access to information, research, and communication forums where community members can connect to each other and collaborate on all types of issues regarding resiliency
- Social and cultural celebrations, ceremonies, and activities
- Access to parks and green space to maintain physical, spiritual and emotional health
- Increased biodiversity/diversity

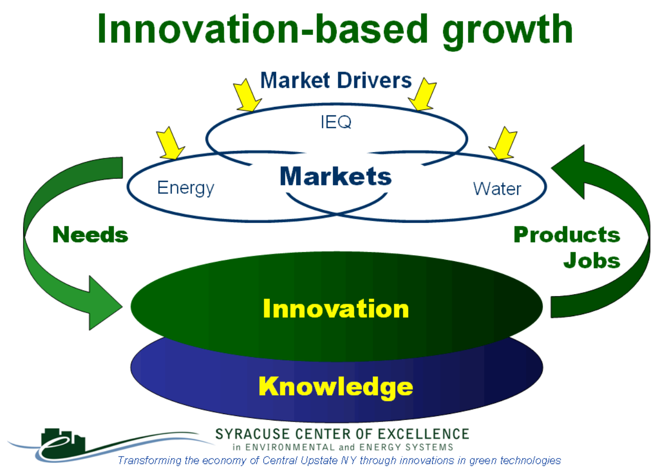
> *Resilience shifts attention from purely growth and efficiency to needed recovery and flexibility. Growth and efficiency alone can often lead ecological systems, businesses and societies into fragile rigidities, exposing them to turbulent transformation. Learning, recovery and flexibility open eyes to novelty and new worlds of opportunity.*
>
> The Resilience Alliance (resilience.org)

Environmental decisions made by individuals, civil society, and the state involve questions of economic efficiency, environmental effectiveness, equity, and political legitimacy. These four criteria are constitutive of the economic and environmental dimensions of sustainable development, which has become the dominant rhetorical device of environmental governance. More importantly, they help define the social structure and attributes—the third leg of sustainability—of a resilient community.

It is argued that a social structure that is more organic is more resilient, such as the social structure of indigenous peoples of the Americas, which are traditionally long-lived societies. In an archetypical indigenous social structure, humans are subject to natural laws instead of humans controlling destiny with unlimited resources. It is recognized that all species are differently gifted, but are not fundamentally different; we are all related and humans are a part of nature. The principle of seven generations takes into account the long-term perspective of native peoples (for every action taken, consider the impact on seven generations in the future). The social organization is non-hierarchical, where efficiency is valued along with the holistic combination of mental, physical, emotional, and spiritual knowledge. In indigenous social structure, reciprocal responsibility drives economic and social organization, time and history are circular, and technology should be appropriate and balanced against impacts. The community, thus, is resilient.

Syracuse Center of Excellence (CoE) and Resilience

The activities of the SyracuseCoE, an industry-university collaborative organization that creates environmental and energy innovations for a sustainable future—one looking at least seven generations hence—is key to resilient local populations in several ways. First, the business model or innovation platform is a system for facilitating the creation, validation, and commercialization of products and services in environmental and energy systems (see figure below). Second, the SyracuseCoE focus areas are air, energy, and water—all vital systems to serve life and populations. Finally, the outreach and workforce development programs of the SyracuseCoE are striving to create jobs and well being for the community and region as a whole.



Innovations facilitated by the SyracuseCoE in its three focus areas have led to the development of devices and systems that can protect people, buildings, water supplies, energy systems, and communities during times of stress.

For example, to protect air quality in buildings SyracuseCoE researchers are exploring systems to detect contaminants in HVAC systems and intelligently control the operation if an agent is found. This type of system can be used to understand more about when buildings or cities are safe after a catastrophic event. Also, SyracuseCoE partner companies have built devices that can be used in emergency events such as pandemics, biological attacks, or massive fires.

In the water area, SyracuseCoE is leading efforts to explore alternatives to centralize water and wastewater treatment systems. By providing natural treatment areas through green infrastructure, large capital wastewater projects can be avoided. These natural systems also provide redundancy in systems. Similar to buildings and air, SyracuseCoE researchers and companies are creating systems to detect toxins in water and monitoring networks that provide background data that can be used to determine when there might be a perturbation in a system whether intentional or not. Related, as society addresses climate change it is paramount to have background data and models to interpret how the global community will respond to changes in GHG levels in the atmosphere.

In the energy area, research and commercialization activities in different technologies such as solar, micro-hydro, and geothermal systems provide redundancy and opportunities for the development of distributed energy systems. Renewable energy systems promote resilience by moving away from carbon-intensive fossil fuels and centralized power grids. As seen in August 2003, the fragility of the Northeast grid was evident when 50 million people lost power due to an event at in Ohio.

Equally important to new technologies in the energy area is SyracuseCoE's emphasis on sustainability, energy efficiency, and green buildings for communities. Paying heed to site attributes, taking a holistic approach for design, and using healthy materials result in buildings and communities that work with natural systems rather than against them.

SyracuseCoE recognizes the societal need of what it does. Consider the following reality. More than 70% of electricity and more than 40% of energy consumed in the U.S. is used to heat, light, ventilate, cool, and power buildings. Poor indoor environmental quality (IEQ) in buildings causes adverse impacts on occupants' performance and/or health, which are estimated to cost the U.S. economy $60 billion annually. A confluence of rising public concerns—including the impact of buildings on global climate change, the cost and availability of traditional energy sources, and the effects of poor IEQ on human health and performance—drive the need for innovations that increase energy efficiency of buildings while simultaneously improving IEQ for occupants.

As a key cornerstone of economic development for the Syracuse and Central Upstate NY region, SyracuseCoE programs are helping to create employment opportunities for individuals. Revitalization of communities such as the Near West Side of Syracuse through sustainable projects such as LEED-ND is critical for rebuilding and supporting the social infrastructure of neighborhoods. Workforce development programs in green construction, deconstruction, weatherization, and green infrastructure provide a nexus that enable individuals to earn living wages to support their families as well as contribute to the overall environmental health of their community. The creation and maintenance of green spaces and public parks lead to the creation of systems that provide buffering during extreme weather events and enable physical and spiritual connections to nature.

SyracuseCoE Resilience Projects: Examples

Focus Area One: Air

- **Smart Buildings:** Promote the development of *Smart Buildings.* Some examples:
  - Sensor development: R&D on smart sensors, nano-materials at Syracuse University
  - Computational fluid dynamic modeling of contaminant/particle transport within systems at Clarkson University
  - Sensor deployment and networks for early detection at Syracuse University

- **Clean/Safe Spaces:** Ability to create clean/safe spaces. Some examples:
  - Portable Contamination Control Unit—*Isolation Air* by Air Innovations (www.airinnovations.com/IsolationAir.asp)
    - Creates negative or positive pressure, quickly and easily
    - Combines pre-filter, dual UVC germicidal lights and a 99.99% HEPA filter for optimal air purification against many airborne biological contaminants, mold bacteria and viruses
    - Provides air conditioning for patient and staff comfort
    - Isolates room from central system to limit potential of cross-contamination
    - Self-contained and portable, using standard 110-volt outlet
    - Applications for use include hospital rooms (e.g., burn, trauma, infectious disease)
  - Positive/Negative Pressure Isolation Enclosure—Isolation Sciences (www.isolationsciences.com/posneg.html)
    - This technology has applications for medical shelters used during any pandemic mass casualty event or Katrina-like emergency disaster to isolate highly infectious patients and or to keep any exterior air contaminate from entering the occupant space used to house immune-suppressed patients.

Focus Area Two: Energy

- **Clean & Renewables:** Development of new fuels and technologies, such as:
  - Algae Based Biodiesel
  - Cellulosic Ethanol
  - Solar
  - Small wind
  - Small hydro
- **Efficiency:** Some examples of energy efficiency programs:
  - Freewatt furnace: Micro combined heat and power demonstration in Near West Side home
  - Green buildings
  - Weatherization programs
  - Smart appliances and grid
- **Generation:** Promote diversity of sources for production and carbon neutrality
- **Storage:** Ability to store energy is key and obviates the need for a central grid
  - Batteries
  - Fuel cells
  - Transportation

Focus Area Three: Water

- **Distributed Systems:** Distributed systems for water and waste water treatment
- **Early Warning:** Early warning detection systems. Some examples:
  - Orthosystems
  - Source Sentinel
- **Green Infrastructure:** Less reliance on central, capital intensive treatment plants
- **Sensor Networks:** Sensor deployment and networks for decision making and management
  - Syracuse University/Upstate Freshwater Institute robotic network
- **Sustainable Infrastructure Management Practices:** Promote the 4-pillars of sustainable infrastructure management:
  - Better Management skills
  - Full-Cost Pricing
  - Watershed/Ecosystem Approach
  - Water Use Efficiency
- **Sustainable Planning:** Water use planning and management, landscape and urban planning, land use planning

Program Delivery: Green Workforce Development & Outreach

- **Community of Learners**
- **Deconstruction**
- **Green Construction**
- **Social Networks:** Building on neighborhoods, strong social networks to help unemployed, underemployed to find opportunities and succeed

Program Delivery: SyracuseCoE Business Model

- **Academic/Business Nexus:** A nexus to create "intellectual collisions"
- **Creative Community:** Creative ideas along the continuum
- **Innovation Platform:** Programs in place to create, nurture, and commercialize relevant technologies and services

Resilience Theory As Applied

According to the Resiliency Alliance, the basic concepts underpinning a resilience approach to policy and management are: non-linearity, alternate regimes and thresholds; adaptive cycles; multiple scales and cross-scale effects ("panarchy"); adaptability; transformability; and, general versus specified resilience.

- ***Non-linearity, Alternate Regimes and Thresholds***

  Because of non-linear dynamics, many systems can exist in what are called alternate stable states. The term "states" is often used loosely and can be confusing, so it needs to be defined. The state of a system at any time is defined by the values (amounts) of the variables that constitute the system. As biophysical and social attributes of the system change, the positions of the attractors move around, and the various basins of attraction get smaller and larger, or appear and disappear.

- ***Adaptive Cycles***

  Social-Environmental Systems, like all systems, are never static, and they tend to move through four, recurring phases, known as an adaptive cycle. Generally, the pattern of change is a sequence from a rapid growth phase through to a conservation phase in which resources are increasingly unavailable, locked up in existing structures, followed by a release phase that quickly moves into a phase of reorganization, and thence into another growth phase. However, multiple possible transitions among the four phases are possible and the pattern may not reflect a cycle.

- ***Multiple Scales and Cross-scale Effects ("Panarchy")***

  No system can be understood or managed by focusing on it at a single scale. All systems exist and function at multiple scales of space, time and social organization, and the interactions across scales are fundamentally important in determining the dynamics of the system at any particular focal scale. This interacting set of hierarchically structured scales has been termed a "panarchy" (Gunderson and Holling 2003).

- ***Adaptability***

  Adaptability is the capacity of a Social-Environmental System to manage resilience in relation to alternate regimes (sometimes called adaptive capacity). It involves either or both of two abilities:

  - *The ability to determine the trajectory of the system state - the position within its current basin of attraction;*
  - *The ability to alter the shape of the basins, that is move the positions of thresholds or make the system more or less resistant to perturbation.*

  The abilities to effect both of these are determined by a combination of attributes of both the social domain and the ecosystem.

- ***Transformability***

  In cases where a system is already in an undesirable regime and efforts to get it back into a desirable regime are no longer possible (or worse, make the undesirable basin larger), one *option for resolving the predicament is transformation to a different kind of system—new variables, new ways of making a living, different scales—a different panarchy.*

- ***General vs. Specified Resilience***

One can think about "specified" resilience as the resilience "of what", "to what". This should be the focus—the resilience of some aspect of a system (its productivity, the species it contains, the livelihoods of people) to some defined shocks (a drought, a fire, a market shift). However, efforts to increase resilience of some aspect of a system regime to a specified set of disturbances can unwittingly reduce the resilience of other aspects of that system to other, non-specified (perhaps novel) disturbances. There is therefore a need to balance the maintenance of general resilience while engaged in necessary efforts to enhance specified resilience to known threats and disturbances. It is a difficult issue to address.

From The Resilience Alliance (resilience.org)

Resilience Alliance Related Sources

Allen, C.R., L. Gunderson, and A.R. Johnson. 2004. *The use of discontinuities and functional groups to assess relative resilience in complex systems*. Ecosystems 8: 958-966.

Anderson, K., and M.A. Janssen. 2004. *Institutional innovation and adaptive management: learning from Bolivia's decentralization experiment.* Pages 63-78 in S.S. Light, editor. The Role of Biodiversity Conservation in the Transition to Rural Sustainability, IOS Press Amsterdam.

Ayre, D.J. and T.P. Hughes. 2004. *Climate change, genotypic diversity and gene flow in reef-building corals*. Ecology Letters 7:273-278.

Barthel, S., J. Colding, T. Elmqvist, and C. Folke. 2005. *History and local management of a biodiversity-rich, urban cultural landscape*. Ecology and Society 10(2): 10. [online].
www.ecologyandsociety.org/vol10/iss2/art10/

Bellwood, D.R., and T.P. Hughes. 2001. *Regional-scale assembly rules and biodiversity of coral reefs.* Science. 292: 1532-1534.

Brock, W.A., and A. Xepapadeas. 2002. *Biodiversity management under uncertainty: species selection and harvesting rules*. Pages 62-97 in P. Dasgupta, B. Kriston, and K.G. Lofgren, editors. Economic Theory for the Environment: Essays in honour of K.G. Maler. Edward Elgar, Cheltenham, UK.

Brock, W.A., and A. Xepapades. 2003. *Valuing biodiversity from an economic perspective: a unified economic, ecological and genetic approach*. Pages 1597-1614. The American Economic Review Vol.93, No. 5. SSRI Reprint #496.

Brown, K., 2004. *Trade-off analysis for integrated conservation and development*. In T. McShane, and M. Wells, (eds) Getting Biodiversity Projects to Work: Towards More Effective Conservation and Development. Columbia University Press, New York pp289-316.

Carpenter, S., B. Walker, J. M. Anderies, and N. Abel. 2001. *From metaphor to measurement: Resilience of what to what?* Ecosystems 4:765-781.

Carpenter, S. R. and W. A. Brock. 2004. *Spatial complexity, resilience and policy diversity: fishing on lake-rich landscapes*. Ecology and Society 9 (1):8. [online]. www.ecologyandsociety.org/vol9/iss1/art8

Carpenter, S. R. and W. A. Brock. 2004. *Spatial complexity, resilience and policy diversity: fishing on lake-rich landscapes*. Ecology and Society 9(1): 8. [online]. www.ecologyandsociety.org/vol9/iss1/art8

Colding J., Folke C., Elmqvist T. 2003. *Social institutions in ecosystem management and biodiversity conservation*. Tropical Ecology 44(1):25-41.

Cumming, D.H.M. 2004. *Performance of parks in a century of change*. Pages 105-124 in B. Child, editor. Parks in transition: biodiversity, rural development and the bottom line. Earthscan, London.

Diaz, R. J. 2001. *Overview of Hypoxia Around the World*. Journal of Environmental Quality 30, no. 2: 275-81.

Dornelas, M., S.R. Connolly and T.P. Hughes. 2006. *Coral reef diversity refutes the neutral theory of biodiversity*. Nature 440: 80-82.

Elmqvist, T., C. Folke, M. Nystrom, G. Peterson, J. Bengtsson, B. Walker, and J. Norberg. 2003. *Response diversity, ecosystem change, and resilience*. Front Ecol Environ 1(9):488-494.

Elmqvist, T., F. Berkes, C. Folke, P. Angelstam, A.-S. Crepín and J. Nimelä. 2004. *The dynamics of ecosystems, biodiversity management and social institutions at high northern latitudes*. Ambio 33:350-355.

Fahrig, L. 2003. *Effects of habitat fragmentation on biodiversity*. Annual Reviews of Ecology and Systematics 34: 487-515.

Folke, C., S. Carpenter, B. Walker, M. Scheffer, T. Elmqvist, L. Gunderson and C.S. Holling. 2005. *Regime shifts, resilience and biodiversity in ecosystem management*. Annual Review of Ecology Evolution and Systematics 35: 557-581.

Folke, C., S. Carpenter, B. Walker, M. Scheffer, T. Elmqvist, L. Gunderson and C.S. Holling. 2004. *Regime shifts, resilience and biodiversity in ecosystem management*. Annual Review of Ecology Evolution and Systematics 35:557-581.

Folster, H. 1994. *Stability of Forest Ecosystems in the Humid Tropics*. Interciencia 19, no. 6: 291-96.

Garmestani, A. S., C. R. Allen, J. D. Mittelstaedt, C. A. Stow, and W. A. Ward. 2006. *Firm size diversity, functional richness and resilience*. Environment and Development Economics 11(4): 533-551.

Heal G., B. Walker, S. Levin, K. Arrow, P. Dasgupta, G. Daily, P. Ehrlich, K-G. Maler, N. Kautsky, J. Lubchenco, S. Schneider, and D. Starret. 2004. *Genetic diversity and interdependent crop choices in agriculture*. Resource and Energy Economics 26: 175-184.

Holling, C. S. 1973. *Resilience and stability of ecological systems*. Annu Rev Ecol Syst 4:1-23.

Holling, C. S. 1996. *Engineering resilience versus ecological resilience*. Pages 31-44 in P. Schulze , editor. Engineering within ecological constraints. National Academy Press, Washington, D.C.

Hughes, T.P, T.R. Bellwood, and S.R. Connelly. 2002. *Biodiversity hotspots, endemicity and the conservation of coral reefs*. Ecology Letters 5:775-784.

Ivany, L. C. 1996. *Coordinated Stasis or Coordinated Turnover? Exploring Intrinsic Vs Extrinsic Controls on Pattern*. Palaeogeography Palaeoclimatology Palaeoecology 127, no. 1-4: 239-56.

Jeppesen, E., J. P. Jensen, M. Sondergaard, T. Lauridsen, and F. Landkildehus. 2000. T*rophic Structure, Species Richness and Biodiversity in Danish Lakes: Changes Along a Phosphorus Gradient*. Freshwater Biology 45, no. 2: 201-18.

Leibold M., and J. Norberg. 2004. *Plankton biodiversity in metacommunities, ponds as complex complex adaptive systems*. Limnology and Oceanography, vol. 49, no. 4, part 2.

Matter, S. F., I. Hanski, and M. Gyllenberg. 2002. *A Test of the Metapopulation Model of the Species-Area Relationship*. Journal of Biogeography 29, no. 8: 977-83.

Matutinovic, I. 2001. *The Aspects and the Role of Diversity in Socioeconomic Systems: an Evolutionary Perspective*. Ecological Economics 39, no. 2: 239-56.

Metzger, J. P., and H. Decamps. 1997. *The Structural Connectivity Threshold: an Hypothesis in Conservation Biology at the Landscape Scale*. Acta Oecologica-International Journal of Ecology 18, no. 1: 1-12.

Norberg, J. 2004. *Biodiversity and ecosystem functioning: a complex adaptive systems approach*. Limnology and Oceanography, vol. 49, no. 4, part 2.

Perrings, C., and B. Walker. 1997. *Biodiversity, Resilience and the Control of Ecological-Economic Systems: the Case of Fire-Driven Rangelands*. Ecological Economics 22, no. 1: 73-83.

Peterson, G., C. R. Allen, and C. S. Holling. 1998. *Ecological resilience, biodiversity and scale*. Ecosystems 1:6-18.

Peterson, G., C. R. Allen, and C. S. Holling. 1998. *Ecological Resilience, Biodiversity, and Scale*. Ecosystems 1, no. 1: 6-18.

Ray, J. C., K. H. Redford, J. Berger, and R. S. Steneck. 2005. *Is large carnivore conservation equivalent to biodiversity conservation and how can we achieve both?* Pages 400 - 428 in Ray, J., Redford, K., Steneck, R. and Berger, J.(eds) Large Carnivores and the conservation of biodiversity. Island Press.

Sala, O. E., D. van Vuuren, H. Pereira, D. Lodge, J. Alder, G. S. Cumming, A. Dobson, V. Wolters, and M. A. Xenopoulos. (2005). *Biodiversity across scenarios*. Chapter 10 in: Millennium Ecosystem Assessment Volume 2: Scenarios Assessment.

Scheffer, M., S. Carpenter, J. A. Foley, C. Folke, and B. Walker. 2001. *Catastrophic shifts in ecosystems*. Nature 413:591-596.

Steneck, R. S. 2005. *An ecological context for the role of large carnivorous animals in conserving biodiversity*. Pages 9 - 33 in Ray, J., Redford, K., Steneck, R. and Berger, J.(eds) Large Carnivores and the conservation of biodiversity. Island Press. Washington, D.C.

Steneck, R. S. and Sala, E. A. 2005. *Large marine carnivores: trophic cascades and top-down controls in coastal ecosystems past and present*. Pages 110 - 137 in Ray, J., Redford, K., Steneck, R. and Berger, J. (eds) Large Carnivores and the conservation of biodiversity Island Press.

Steneck, R. S., Graham, M. H. , Bourque, B. J., Corbett, D., Erlandson, J. M, Estes, J. A., and Tegner, M. J. 2002. *Kelp forest ecosystem: biodiversity, stability, resilience and their future*. Environmental Conservation. 29 (4): 436 - 459.

Talent, J. A., R. Mawson, A. S. Andrew, P. J. Hamilton, and D. J. Whitford. 1993. *Middle Paleozoic Extinction Events - Faunal and Isotopic Data*. Palaeogeography Palaeoclimatology Palaeoecology 104, no. 1-4: 139-52.

Vinebrooke, R.D., K.L. Cottingham, J. Norberg, M. Scheffer, S.I. Dodson, S.C. Maberly, and U. Sommer. 2004. *Impacts of multiple stressors on biodiversity and ecosystem functioning: the role of species co-tolerance*. OIKOS 104:451-457.

Walker, B. 1989. *Diversity and stability in ecosystem conservation*. In: Conservation for the Twenty-first Century. Editors: D. Western, and M. Pearl, 121-30. London: Oxford University Press.

Walker, B.H., and J.L. Langridge. 2002. *Measuring functional diversity in plant communities with mixed life forms: a problem of hard and soft attributes*. Ecosystems 5: 529-538.

Walker, B., S. Carpenter, J. Anderies, N. Abel, G. Cumming, M. Janssen, L. Lebel, J. Norberg, G. D. Peterson, and R. Pritchard. 2002. *Resilience management in social-ecological systems: a working hypothesis for a participatory approach*. Conservation Ecology 6(1): 14. [online]. www.consecol.org/vol6/iss1/art14

Weatherby, A. J., P. H. Warren, and R. Law. 1998. *Coexistence and Collapse: an Experimental Investigation of the Persistent Communities of a Protist Species Pool*. Journal of Animal Ecology 67, no. 4: 554-66.

Zinsmeister, W. J. 1998. *Discovery of Fish Mortality Horizon at the K-T Boundary on Seymour Island: Re-Evaluation of Events at the End of the Cretaceous*. Journal of Paleontology 72, no. 3: 556-71.

Zinsmeister, W. J. 2002. *Mass Mortalities and Mass Extinction*. Lethaia 35, no. 1: 20.