STOCKHOLM ENVIRONMENT INSTITUTE

Poverty and Vulnerability Programme
GECAFS Project

Resilience and vulnerability

Resilience emerged in the 1970s in ecology as an integrating concept, later extended to social science and 'coupled socio-ecological systems'. In the resilience community (Resilience Alliance) vulnerability arises from the loss of resilience. Determining levels of resilience is less a specific methodology, although cyclical behaviour of a system and the positive and negative feedbacks are common elements. While resilience emphasizes the system, vulnerability often looks at individual actors and vulnerable populations.

Introduction

The concept of resilience emerged in ecology and the social sciences during the 1970s and 80s in recognition that nature is inherently dynamic. Its intervention was specifically linked to critiques of equilibrium theories of environmental science. "The equilibrium centred view is essentially static and provides little insight into the transient behaviour of systems that are not near the equilibrium." (Holling 1973: 2). Dynamic, non-linear thinking about natural processes led to Holling's 'science of surprise' (Holling 1986). The metaphor invoked was of a ball in a bowl-shaped valley that every now and then flips into another bowl-shaped valley. The ball was seen to 'jump between stability domains'. Resilience here was seen to be 'the ability of a system to maintain its structure and patterns of behaviour in the face of disturbance' (Holling 1986: 296). Holling (1986) also argued that ecosystems go through regular cycles of organization, collapse and renewal: the adaptive renewal cycle.

Defining resilience

Holling's summarization that "Resilience determines the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state."(Holling 1973: 17) spawned a long and derivatory chain of definitions (MacGillivray and Grime 1995). Today a more complex definition is offered by the Resilience Alliance. Here resilience infers: i) the amount of change the system can undergo and still retain the same controls on function and structure, or still be in the same state within the same domain of attraction; ii) the degree to which the system is capable of self-organization; iii) the ability to build and increase the capacity for learning and adaptation (Berkes, Colding, and Folke 2003: 13). The added dimension here encompasses the practical issues of capacitation and adaptation and is summarized by (Seixas and Berkes 2003: 272) as follows: "The resilience of an ecosystem is its capacity to absorb disturbances while maintaining its behavioural processes and structure. It can be defined as the capacity to buffer perturbations, to self-organize, and to learn and adapt." The Resilience Alliance definition is orientated towards both social and ecological systems and precludes the need for further definitions of social resilience (Adger 2000: 347) which in any case is seen as connected to biogeophysical resilience.

Relevance of resilience to vulnerability

The link between resilience and vulnerability science is as follows. Vulnerability comes from a loss of resilience (Holling 1995: 24). A system become an accident waiting to happen. Fire become more and more likely as the amount and flammability of fuel accumulates. Insect outbreak is triggered by weakened trees (Ibid.). If we consider both social and ecological systems to be inherently dynamic, then levels of vulnerability will increase in direct proportion to reduced levels of resilience, which connotes reduced variability of ecosystems, and reduced options for coping with sudden and unexpected change. Resilience is probably the second instinct, after survival, of all species. From a practical perspective, it is a 'belt-and-braces' approach to planetary self-preservation and to evading widespread extinction. Folke (2003: 355) summarized the four essential measures that social-ecological systems need to take to enhance resilience and thus reduce vulnerability as: a) learning to live with change and uncertainty; b) Nurturing diversity for reorganization and renewal - nurturing ecological memory, sustaining social memory; c) Combining different types of knowledge for learning; d) Creating opportunity for self-organization - matching scales of ecosystems and governance - dealing with cross-scale dynamics. A practical example of the link between resilience and vulnerability might be the work done in the Netherlands in reducing the potential impact of climate change on coastal ecosystems through 'managed retreat' (Klein et al. 1998) where 'managed retreat involves allowing the coastline to recede to a new line of defence in order to restore natural coastal processes and thereby natural coastal systems such as mudflats, saltmarsh areas and dunes, thus reduces coastal vulnerability (Ibid.: 260).

Methods for examining resilience

"Resilience and stability should be measurable. There are two components that are important: one that concerns the cyclic behaviour and its frequency and amplitude, and one that concerns the configuration of forces caused by positive and negative feedback relations." (Holling 1973: 19). Four case studies will be discussed in brief where resilience has been measured and analysed in field studies. These concern: i) insectivorous birds and forest renewal in Canada (Berkes, Colding, and Folke 2003); ii) nurturing diversity in Samoa (Colding, Elmqvist, and Olsson 2003); iii) sudden change in the Baltic Sea (Jansson and Velner 1995); and iv) analyzing management strategies that weaken or strengthen resilience in a lagoon fishery in Brazil (Seixas and Berkes 2003). Determining levels of resilience - such as noting various forms of diversity (livelihood, crop, species etc.)– is less a specific methodology, more a variety of data collection procedures designed and later codified to answer specific research questions about levels of resilience at a range of spatial and temporal scales.

Case studies

i) The assemblage of migratory insectivorous bird populations is one of the controlling factors of forest renewal produced by budworm population cycles. The existence of these birds contributes to the resilience of the boreal forest in Canada. Mathematical simulations based on long term studies have indicated that the total bird population would have to be reduced by about 75% before the system might flip out of the current domain of attraction and into a different one. Bird census data is therefore utilized as perhaps the primary method for maintaining a check on levels of resilience. (Berkes, Colding, and Folke 2003)p.14.

ii) Samoan polyculture is still practiced to a significant degree but in the Cook Islands and French Polynesia it has largely disappeared and been replaced by cash crop monocultures (Colding, Elmqvist, and Olsson 2003: 167). Research in the Samoan archipelago into the impacts of the 1990 and 1991 tropical cyclone revealed that cash crops were damaged more than subsistence crops. It was therefore concluded that in areas where tropical cyclones occur a diverse set of crops and cultivars may reduce the risk of total loss of food supply. Techniques for emergency food storage were among several resilience strategies examined to cope with unpredictable disturbances. A tradition in many Polynesian islands is the use of a sophisticated method for fermenting breadfruit in pits. This fermentation makes long-term food storage possible in a hot and humid climate (Colding, Elmqvist, and Olsson 2003: 167).

iii) learning to live with uncertainty involves a wide range of strategies of which water and food storage and environmental protection are the most obvious. Residents of one of the most fragile natural systems in Northern Europe, the Baltic Sea, have certainly learned to fear the unexpected. The sudden collapse, during the eighteenth century, of the Baltic herring fisheries has been echoed more recently by the overexploitation of cod and salmon. Between 1975 and 1985 the total biomass of Baltic fish fell by almost 30% and the decline continues. As if overfishing problems were not enough, the environmental disaster that the widespread use of DDT brought to the region in the 1950s, coupled with bouts of acid rain, helped to ferment the Scandinavian commitment to environmental protection that was emphasized so forcefully in the 1987 Brundtland Commission report. It was seen during the period of research that the magnitude of the Baltic crises covered a range of spatial scales, from loss of species abundance (eg. white-tailed eagle, porpoise, ringed seal, grey seal) to changed subsystems (Ibid.: 357). Methodologies developed for assessing resilience in the field should at all times take into account potential impacts at a variety of scales. This is particularly important when considering large-scale social or biogeophysical drivers such as global tourism or climate variability as inherently connected to local livelihoods or ecosystem survival.

iv) As ecosystems are hierarchically structured into a number of levels, many adaptive renewal cycles are linked through time and space, termed *panarchy* by Gunderson and Holling (2002). At least two features of panarchy (or cross-scale interaction) may help to understand resilience: 1) disturbance in the small scale system can cascade to the broader scale. 2) a large-scale system can provide resources (by 'remembering' or carrying over elements through its release phase) for the renewal phase of the smaller-scale system. The term *panarchy* is used to capture the dynamic of adaptive cycles that are nested within one another across space and time scales. In the typical boreal forest, for example, fresh needles cycle yearly; the crown of the foliage cycles with a decadal period; and trees, gaps and stands cycle at a period of about a century or more. The result is a hierarchy in which each level has its own spatial and temporal attributes (Holling 1995: 23).

The Ibiraquera Lagoon on Brazil's Atlantic coast is a good example of a small ecosystem going through the adaptive renewal cycle. Following Holling's (1986) adaptive renewal cycle the release stage is the few hours from time the channel bursts through the sandbar to the time the lagoon water level matches the water level of the ocean; that is, the period it takes to drain the excess water of the lagoon. The renewal stage is the period the channel remains open, which can vary from a few days to a few months. In this stage the lagoon's saltwater and fish and shrimp stocks are renewed. Outside the scope of study, but important, is that changes in the ocean ecosystem such as an oilspill or overexploitation of shrimp and mullet stocks would affect the lagoon ecosystem.

The history of the Ibiraquera Lagoon fishery is especially interesting as it shows the resilient 'traditional' management system of the 1960s transforming into less resilient and non-viable system of 1970-1981 rebuilding resilience after experiencing a crisis (1981-94) and regressing again after 1994. Lessons learnt through the research exercise were that factors that weaken social-ecological resilience were: i) Breakdown of traditional institutions and authority system; ii) Rapid technological changes eg. more efficient fishing gear; iii) Rapid changes in local economy during 1970s when fishing profits became more and more important; iv) Fishery inspector positions were eliminated leading to enforcement crisis.

Five key factors that strengthen resilience in this context were:: i) Strong institutions; ii) Cross-scale communication; iii) Political space for experimentation; iv) Social justice; v) Use of ecological knowledge. Communication became especially useful in successfully banning all nets but cast nets, banning gas lamps and increasing shrimp cast net mesh size involved cross-scale communication and cooperation (Seixas and Berkes 2003).

Conclusion

Resilience is a key concept in the rapidly growing field of socio-ecological studies. Resilience tends to be applied to systems, whereas vulnerability analysis has focused on human exposure units (e.g., marginal populations). However, vulnerability studies have tended to focus on the near term and need to incorporate the dynamics of ecosystem services and functions in more realistic ways in order to evaluate the longer term evolution of vulnerability. Both groups would benefit from a closer dialogue.

Acknowledgements

This work was supported through the Sida Poverty and Vulnerability Programme and the UK Economic and Social Research Council.

References

Adger, N. W. 2000. Social and ecological resilience: are they related? *Progress in Human Geography* 24:347-64.

Berkes, F., J. Colding, and C. Folke. 2003. *Navigating Social-Ecological Systems: Building Resilience for Complexity and Change*. Cambridge: Cambridge University Press.

Colding, J., T. Elmqvist, and P. Olsson. 2003. "Living with disturbance: building resilience in social-ecological systems," in *Navigating Social-Ecological Systems: Building Resilience for Complexity and Change*. Edited by F. Berkes, J. Colding, and C. Folke, pp. 163-185. Cambridge: Cambridge University Press.

Holling, C. 1995. "What Barriers? What Bridges?" in *Barriers and Bridges to the Renewal of Ecosystems and Institutions*. Edited by L. Gunderson, C. S. Holling, and S. Light. New York: Columbia University Press.

Holling, C. M. 1986. "The resilience of terrestrial ecosystems: local surprise and global change," in *Sustainable Development of the Biosphere*. Edited by W. C. Clark and R. E. Munn, pp. 292-317. Cambridge: Cambridge University Press.

Holling, C. S. 1973. Resilience and stability of ecological systems. *Annual Review in Ecology and Systematics* 4:1-23.

Jansson, B.-O., and H. Velner. 1995. "The Baltic: The Sea of Surprises," in *Barriers and Bridges to the Renewal of Ecosystems and Institutions*. Edited by L. Gunderson, C. S. Holling, and S. Light, pp. 292-372. New York: Columbia University Press.

Klein, R., M. Smit, H. Goosen, and C. Hulsbergen. 1998. Resilience and Vulnerability: Coastal Dynamics of Dutch Dikes. *The Geographical Journal* 164:259-268.

MacGillivray, C. W., and J. P. Grime. 1995. Testing Predictions of the Resistence and Resilience of vegetation Subjected to Extreme Events. *Functional Ecology* 9:640-649.

Seixas, C., and F. Berkes. 2003. "Dynamics of social-ecological changes in a lagoon fishery in southern Brazil," in *Navigating Social-Ecological Systems: Building Resilience for Complexity and Change*. Edited by F. Berkes, J. Colding, and C. Folke. Cambridge: Cambridge University Press.

Other relevant briefing notes

- Vulnerability, global environmental change and food systems (overview of vulnerability concepts)
- Vulnerability assessment and mapping (use of indicators)
- Political ecology: Contributions to vulnerability concepts and methods
- Vulnerability toolkit (overview of range of tools for vulnerability assessment)
- Agent based modeling of vulnerable food systems
- Choosing methodology

Stuart Franklin
Tom Downing
SEI Oxford

Contacts:

Tom Downing, tom.downing@sei.se

Stuart Franklin, stuart.franklin@sei.se

Poverty and Vulnerability documents and discussions: www.VulnerabilityNet.org

GECAFS: www.Gecafs.org