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Insight

Resilience Thinking: Integrating Resilience, Adaptability and Transformability

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ABSTRACT. Resilience thinking addresses the dynamics and development of complex social–ecological systems (SES). Three aspects are central: resilience, adaptability and transformability. These aspects interrelate across multiple scales. Resilience in this context is the capacity of a SES to continually change and adapt yet remain within critical thresholds. Adaptability is part of resilience. It represents the capacity to adjust responses to changing external drivers and internal processes and thereby allow for development along the current trajectory (stability domain). Transformability is the capacity to cross thresholds into new development trajectories. Transformational change at smaller scales enables resilience at larger scales. The capacity to transform at smaller scales draws on resilience from multiple scales, making use of crises as windows of opportunity for novelty and innovation, and recombining sources of experience and knowledge to navigate social–ecological transitions. Society must seriously consider ways to foster resilience of smaller more manageable SESs that contribute to Earth System resilience and to explore options for deliberate transformation of SESs that threaten Earth System resilience.

Key Words: *adaptability; adaptation; resilience; social-ecological systems; transformability; transformation*

INTRODUCTION

One of the most cited papers in *Ecology and Society* was written to exposit the relationships among resilience, adaptability and transformability (Walker et al. 2004). That paper defined resilience as “the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks” (Walker et al. 2004:4).

Discussions since publication of that paper have exposed some confusion about the use of the term resilience. The idea that adaptation and transformation may be essential to maintain resilience may at first glance seem counterintuitive, as it embraces change as a requisite to persist. Yet the very dynamics between periods of abrupt and gradual change and the capacity to adapt and transform for persistence are at the core of the resilience of social–ecological systems (SESs). We therefore strive to develop a theoretical framework for understanding what drives SESs, centered around the idea of resilience. We term this framework resilience thinking. Here we rephrase the three core elements of resilience thinking to embrace these ideas.

RESILIENCE: THE HISTORY OF A CONCEPT

Resilience was originally introduced by Holling (1973) as a concept to help understand the capacity of ecosystems with alternative attractors to persist in the original state subject to perturbations, as reviewed by e.g. Gunderson (2000), Folke (2006) and Scheffer (2009). In some fields the term resilience has been technically used in a narrow sense to refer to the return rate to equilibrium upon a perturbation (called engineering resilience by Holling in 1996). However, many complex systems

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have multiple attractors. This implies that a perturbation can bring the system over a threshold that marks the limit of the basin of attraction or stability domain of the original state, causing the system to be attracted to a contrasting state. This is qualitatively different from returning to the original state, and Holling's (1996) definition of ecological or ecosystem resilience has been instrumental to emphasize this difference.

The concept of alternative stable states with clear-cut basins of attraction is a highly simplified image of reality in ecosystems. Attractors may be stable points or more complicated cycles of various kinds. Intrinsic tendencies to produce cyclic or chaotic dynamics are blended in intricate ways with the effects of environmental stochasticity, and with trends that cause thresholds as well as the nature of attractors to change over time. Nonetheless, we observe sharp shifts in ecosystems that stand out of the blur of fluctuations around trends. Such shifts are called regime shifts and may have different causes (Scheffer et al. 2001, Carpenter 2003). When they correspond to a shift between different stability domains they are referred to as critical transitions (Scheffer 2009). All of these concepts have precise definitions in the mathematics of dynamical systems (Kuznetsov 1998, Scheffer 2009).

However, despite their elegance and rigor, they capture only part of reality. One of the main limitations of the dynamical systems theory that forms the broader underlying framework is that it does not easily account for the fact that the very nature of systems may change over time (Scheffer 2009). This implies that, in order to understand the dynamics of an intertwined social–ecological system (SES), other concepts are needed.

In many disciplines, human actions are often viewed as external drivers of ecosystem dynamics; examples include fishing, water harvesting, and polluting. Through such a lens the manager is an external intervener in ecosystem resilience. There are those who suggest constraining the use of the resilience concept to ecosystem resilience, for conceptual clarity, as the basis for practical application of resilience within ecological science and ecosystem management (e.g. Brand and Jax 2007). However, many of the serious, recurring problems in natural resource use and management stem precisely from the lack of recognition that ecosystems and the social systems that use and depend on them are inextricably linked. It is the feedback loops among them, as interdependent social–ecological systems, that determine their overall dynamics.

ADAPTABILITY AND TRANSFORMABILITY AS PREREQUISITES FOR SES RESILIENCE

Social–ecological resilience is about people and nature as interdependent systems. This is true for local communities and their surrounding ecosystems, but the great acceleration of human activities on earth now also makes it an issue at global scales (Steffen et al. 2007), making it difficult and even irrational to continue to separate the ecological and social and to try to explain them independently, even for analytical purposes. To put the issue in context, ice core data reveal that humanity has for the last 10,000 years lived in a relatively stable climate, an era referred to as the Holocene. This era has allowed agriculture and all major human civilizations to develop and flourish. The future of human well-being may be seriously compromised if we should pass a critical threshold that tips the earth system out of this stability domain (Rockström et al. 2009). It is plausible that current development paradigms and patterns, if continued, would tip the integrated human–earth system into a radically different basin of attraction (Steffen et al. 2007). Preventing such an undesired critical transition will require innovation and novelty. Profound change in society is likely to be required for persistence in the Holocene stability domain. Alas, resilience of behavioral patterns in society is notoriously large and a serious impediment for preventing loss of Earth System resilience. SES resilience that contributes to Earth System resilience is needed to remain in the Holocene state.

It should be immediately clear from this example that social change is essential for SES resilience. This is why we incorporate adaptability and the more radical concept of transformability as key ingredients of resilience thinking (Table 1).

Adaptability captures the capacity of a SES to learn, combine experience and knowledge, adjust its responses to changing external drivers and internal processes, and continue developing within the current stability domain or basin of attraction (Berkes et al. 2003). Adaptability has been defined as "the capacity of actors in a system to influence resilience" (Walker et al. 2004:5). Thus, adaptive

Table 1. Glossary of resilience terms.

Term	Definition
Active transformation	The deliberate initiation of a phased introduction of one or more new state variables (a new way of making a living) at lower scales, while maintaining the resilience of the system at higher scales as transformational change proceeds.
Adaptability (adaptive capacity)	The capacity of actors in a system to influence resilience.
Adaptive cycle	A heuristic model that portrays an endogenously driven four-phase cycle of social-ecological systems and other complex adaptive systems. The common trajectory is from a phase of rapid growth where resources are freely available and there is high resilience (r phase), through capital accumulation into a gradually rigidifying phase where most resources are locked up and there is little flexibility or novelty, and low resilience (K phase), thence via a sudden collapse into a release phase of chaotic dynamics in which relationships and structures are undone (Ω), into a phase of re-organization where novelty can prevail (α). The r-K dynamics reflect a more-or-less predictable, relatively slow “foreloop” and the Ω - α dynamics represent a chaotic, fast “backloop” that strongly influences the nature of the next foreloop. External or higher-scale influences can cause a move from any phase to any other phase.
Forced transformation	An imposed transformation of a social–ecological system that is not introduced deliberately by the actors.
General resilience	The resilience of any and all parts of a system to all kinds of shocks, including novel ones.
Panarchy	The interactive dynamics of a nested set of adaptive cycles.
Regime	The set of system states within a stability landscape
Regime shift	A change in a system state from one regime or stability domain to another
Resilience	The capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure and feedbacks, and therefore identity, that is, the capacity to change in order to maintain the same identity.
Social–ecological system	Integrated system of ecosystems and human society with reciprocal feedback and interdependence. The concept emphasizes the humans-in-nature perspective
Specified resilience	The resilience “of what, to what”; resilience of some particular part of a system, related to a particular control variable, to one or more identified kinds of shocks.
Stability domain	A basin of attraction of a system, in which the dimensions are defined by the set of controlling variables that have threshold levels (equivalent to a system regime)
Stability landscape	The extent of the possible states of system space, defined by the set of control variables in which stability domains are embedded
Threshold (aka critical transition)	A level or amount of a controlling, often slowly changing variable in which a change occurs in a critical feedback causing the system to self-organize along a different trajectory, that is, towards a different attractor.
Transformability	The capacity to transform the stability landscape itself in order to become a different kind of system, to create a fundamentally new system when ecological, economic, or social structures make the existing system untenable.

capacity maintains certain processes despite changing internal demands and external forces on the SES (Carpenter and Brock 2008). By contrast, transformability has been defined as “the capacity to create a fundamentally new system when ecological, economic, or social structures make the existing system untenable” (Walker et al. 2004:5).

Extending the use of resilience to social–ecological systems makes it possible to explicitly deal with issues raised by Holling (1986) about renewal, novelty, innovation and reorganization in system development and how they interact across scales (Gunderson and Holling 2002). This is an exciting area of explorative work broadening the scope from adaptive management of ecosystem feedbacks to understanding and accounting for the social dimension that creates barriers or bridges for ecosystem stewardship of dynamic landscapes and seascapes in times of change (Gunderson et al. 1995). Are there deeper, slower variables in social systems, such as identity, core values, and worldviews that constrain adaptability? In addition, what are the features of agency, actor groups, social learning, networks, organizations, institutions, governance structures, incentives, political and power relations or ethics that enhance or undermine social–ecological resilience (Folke et al. 2005, Chapin et al. 2006, Smith and Stirling 2010)? How can we assess social–ecological thresholds and regime shifts and what governance challenges do they imply (Norberg and Cumming 2008, Biggs et al. 2009)?

Similarly, it helps to broaden the social domain from investigating human action in relation to a certain natural resource, like dairy or fruit production, or environmental issue, like climate change, to the challenge of multilevel collaborative societal responses to a broader set of feedbacks and thresholds in social–ecological systems (Chapin et al. 2009). For example, governance of the Goulburn-Broken catchment in the Murray Darling Basin, Australia has had to solve problems, adapting to change while continuing to develop, connecting the region to global markets. Dryland cropping, grazing, irrigated dairy and fruit production is widespread and the catchment produces one quarter of the State of Victoria's export earnings (Walker et al. 2009). At a first glance, economically lucrative activities seem to be thriving. But if the analysis is broadened to a social–ecological approach to account for the capacity of the landscape in sustaining the values of the region, the picture looks quite different. Widespread clearing of native vegetation and high levels of water use for irrigation have resulted in rising water tables, creating severe salinization problems; so severe that the region faces serious social–ecological thresholds with possible knock-on effects between them. Crossing such thresholds may result in irreversible changes in the region (Walker et al. 2009). Hence, strategies for adaptability that are socially desirable may lead to vulnerable social–ecological systems and persistent undesirable states such as poverty traps or rigidity traps (Scheffer 2009). Will the adaptability among people and governance of the Goulburn-Broken catchment be sufficient to deal with environmental change, like salinization and interacting thresholds, and avoid being pushed into a poverty trap, or does the social–ecological system need to transform into a new stability landscape, forcing people to change deep values and identity (Walker et al. 2009)?

SPECIFIED AND GENERAL RESILIENCE

In practice, resilience is sometimes applied to problems relating to particular aspects of a system that might arise from a particular set of sources or shocks. We refer to this as specified resilience. In other cases, the manager is concerned more about resilience to all kinds of shocks, including completely novel ones. We refer to this as general resilience.

In social–ecological systems, specified resilience arises in response to the question “resilience of what, to what?” (Carpenter et al. 2001). However, there is a danger in becoming too focused on specified resilience because increasing resilience of particular parts of a system to specific disturbances may cause the system to lose resilience in other ways (Cifdaloz et al. 2010). This is illustrated by the HOT (highly optimized tolerance) theory (Carson and Doyle 2000), which shows how systems that become very robust to frequent kinds of disturbance necessarily become fragile in relation to infrequent kinds. For example, international travel in Europe became increasingly focused on improving and elaborating air travel, with less emphasis on international ground and water transportation. The Icelandic volcano of 2010 exposed the low resilience of this travel system to an extensive cloud of airborne ash that interfered with the operation of passenger jets.

General resilience, in contrast, does not define either the part of the system that might cross a threshold, or the kinds of shocks the system has to endure. It is about coping with uncertainty in all ways. The distinction is important, because our experience in working with groups who are interested in using a resilience approach suggests that they tend to focus on specified resilience, and in doing so they may be narrowing options for dealing with novel shocks and even increasing the likelihood of new kinds of instability. Recognizing that efforts to foster specified resilience will not necessarily avoid a regime shift is a first step to understanding the need for transformational change. Getting beyond the state of denial, particularly in SESs with strong identity or cultural beliefs, is not easy and often requires a shock or at least a perceived crisis. Resilience thinking suggests that such events may open up opportunities for reevaluating the current situation, trigger social mobilization, recombine sources of experience and knowledge for learning, and spark novelty and innovation. It may lead to new kinds of adaptability or possibly to transformational change.

MULTISCALE RESILIENCE AND TRANSFORMABILITY

As defined in Walker et al. (2004), transformational change involves a change in the nature of the stability landscape, introducing new defining state variables and losing others, as when a household adopts a new direction in making a living or when a region moves from an agrarian to a resource-extraction economy. It can be a deliberate process, initiated by the people involved, or it can be forced on them by changing environmental or socioeconomic conditions. Whether transformation is deliberate or forced depends on the level of transformability in the SES concerned.

The attributes of transformability have much in common with those of general resilience, including high levels of all forms of capital, diversity in landscapes and seascapes and of institutions, actor groups, and networks, learning platforms, collective action, and support from higher scales in the governance structure. Transformational change often involves shifts in perception and meaning, social network configurations, patterns of interactions among actors including leadership and political and power relations, and associated organizational and institutional arrangements (e.g. Folke et al. 2009, Huitema and Meijerink 2009, Smith and Stirling 2010).

Deliberate transformational change can be initiated at multiple scales, and perhaps gradually, as suggested by recent experience with applying resilience thinking to catchment planning and management in SE Australia (Walker et al. 2009). Deliberate transformational change at the scale of the whole catchment, of all the component parts at the same time, is likely to be too costly, undesirable or socially unacceptable. Transformational changes at lower scales, in a sequential way, can lead to feedback effects at the catchment scale, which is a learning process, and facilitate eventual catchment-scale transformational change. Actors and organizations that bridge the local to higher social–ecological scales are often involved in such processes (Olsson et al. 2004).

Forced transformation, however, is likely to occur at scales larger than the scale of the management focus and therefore be beyond the influence of local actors. Changes in regional tax structures, for example, may precipitate transformations from farming to suburbanization. Loss of summer sea ice may transform the geopolitical and economic feedbacks among Arctic nations. Systems with high transformative capacity may deliberately initiate transformational changes that shape the outcomes of forced transformations occurring at larger scales.

Transformation trajectories are the subject of a growing literature (Gunderson and Holling 2002, Buchanan et al. 2005, Geels and Kemp 2006, Chapin et al. 2010), A resilience perspective emphasizes an adaptive approach, facilitating different transformative experiments at small scales and allowing cross-learning and new initiatives to emerge, constrained only by avoiding trajectories that the SES does not wish to follow, especially those with known or suspected thresholds. The first part of this process is much the same as that proposed in the socio-technical transitions literature, which encourages arenas for safe experimentation (e.g. Loorbach 2007, Fischer-Kowalski and Rotmans 2009). However, where the transition model then determines the new goal and adopts a particular process for reaching it, a resilience approach would allow the new identity of the SES to emerge through interactions within and across scales.

For example, declining agricultural productivity in several Latin American countries due to land degradation reached an unsustainable level in the 1970s. This breakdown prompted some farmers to start experimenting with unconventional methods for land management, in particular low-till alternatives to plowing that enhanced soil organic matter and fertility (Derpsch and Friedrich 2009). Responses to the land productivity crisis and subsequent social crisis of deteriorated livelihoods were first pursued by individual farmers and researchers in Brazil, Paraguay, and Argentina. Experimentation with new innovative breakthroughs in technologies were necessary, as the shift from then-dominant methods to no-tillage required major changes in land management practices, such as weed management, mulch-farming and green manuring techniques, as well as new machines for direct planting. The experimental learning approach at small scales, with processes for emergence and cross-scale learning, caused a transformation of the whole farming system. Currently, more than 25 million ha of agricultural land is under no-tillage in Brazil alone, and in Latin America the transition from conventional plow-based agriculture to no-till systems has reached a scale where one can talk of an agrarian revolution or a social–ecological transformation (Fowler and Rockström 2001).

Case studies of SESs suggest that transformations consist of three phases: being prepared for or even preparing the social–ecological systems for change, navigating the transition by making use of a crisis as a window of opportunity for change, and building resilience of the new social–ecological regime (Olsson et al. 2004, Chapin et al. 2010). Such transformations are never scale-independent, but draw on social–ecological sources of resilience across scales (Gunderson and Holling 2002). For example, at the Great Barrier Reef a governance transformation across multiple levels of natural resource management took place from protection of selected individual reefs to stewardship of the large-scale seascape. The transformation was triggered by a sense of urgency induced by threats to the reef of terrestrial runoff, overharvesting, and global warming. The Great Barrier Reef Marine Park Authority was crucial in the transformation and provided leadership throughout the process. Strategies involved internal reorganization and management innovation, leading to an ability to coordinate the scientific community, to increase public awareness of environmental issues and problems, to involve a broader set of stakeholders, and to maneuver the political system for support at critical times (Olsson et al. 2008).

Multiscale resilience is fundamental for understanding the interplay between persistence and change, adaptability and transformability. Without the scale dimension, resilience and transformation may seem to be in stark contrast or even conflict. Confusion arises when resilience is interpreted as backward looking, assumed to prevent novelty, innovation and transitions to new development pathways. This interpretation seems to be more about robustness to change and not about resilience for transformation.

The resilience framework broadens the description of resilience beyond its meaning as a buffer for conserving what you have and recovering to what you were. Beyond this concept of persistence, resilience thinking incorporates the dynamic interplay of persistence, adaptability and transformability across multiple scales and multiple attractors in SESs. Fruitful avenues of inquiry include the existence of potential thresholds and regime shifts in SESs and the challenges that this implies; adaptability of SESs to deal with such challenges, including uncertainty and surprise; and the ability to steer away from undesirable attractors, innovate and possibly transform SESs into trajectories that sustain and enhance ecosystem services, societal development and human well-being.

CONCLUSIONS

In a nutshell, resilience thinking focuses on three aspects of social–ecological systems (SES): resilience as persistence, adaptability and transformability. Resilience is the tendency of a SES subject to change to remain within a stability domain, continually changing and adapting yet remaining within critical thresholds. Adaptability is a part of resilience. Adaptability is the capacity of a SES to adjust its responses to changing external drivers and internal processes and thereby allow for development within the current stability domain, along the current trajectory. Transformability is the capacity to create new stability domains for development, a new stability landscape, and cross thresholds into a new development trajectory. Deliberate transformation requires resilience thinking, first in assessing the relative merits of the current versus alternative, potentially more favorable stability domains, and second in fostering resilience of the new development trajectory, the new basin of attraction.

Transformations do not take place in a vacuum, but draw on resilience from multiple scales, making use of crises as windows of opportunity, and recombining sources of experience and knowledge to navigate social–ecological transitions from a regime in one stability landscape to another. Transformation involves novelty and innovation. Transformational change at smaller scales enables resilience at larger scales, while the capacity to transform at smaller scales draws on resilience at other scales. Thus, deliberate transformation involves breaking down the resilience of the old and building the resilience of the new. As the Earth System approaches or exceeds thresholds that might precipitate a forced transformation to some state outside its Holocene stability domain, society must seriously consider ways to foster more flexible systems that contribute to Earth System resilience and to explore options for the deliberate transformation of systems that threaten Earth System resilience.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/vol15/iss4/art20/responses/

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