

# Oxford Research Encyclopedia of Environmental Science

## Resilience

Carl Folke

Subject: Framing Concepts in Environmental Science Online Publication Date: Sep 2016

DOI: 10.1093/acrefore/9780199389414.013.8

## Summary and Keywords

Resilience thinking in relation to the environment has emerged as a lens of inquiry that serves a platform for interdisciplinary dialogue and collaboration. Resilience is about cultivating the capacity to sustain development in the face of expected and surprising change and diverse pathways of development and potential thresholds between them. The evolution of resilience thinking is coupled to social-ecological systems and a truly intertwined human-environment planet. Resilience as persistence, adaptability and, transformability of complex adaptive social-ecological systems is the focus, clarifying the dynamic and forward-looking nature of the concept. Resilience thinking emphasizes that social-ecological systems, from the individual, to community, to society as a whole, are embedded in the biosphere. The biosphere connection is an essential observation if sustainability is to be taken seriously. In the continuous advancement of resilience thinking there are efforts aimed at capturing resilience of social-ecological systems and finding ways for people and institutions to govern social-ecological dynamics for improved human well-being, at the local, across levels and scales, to the global. Consequently, in resilience thinking, development issues for human well-being, for people and planet, are framed in a context of understanding and governing complex social-ecological dynamics for sustainability as part of a dynamic biosphere.

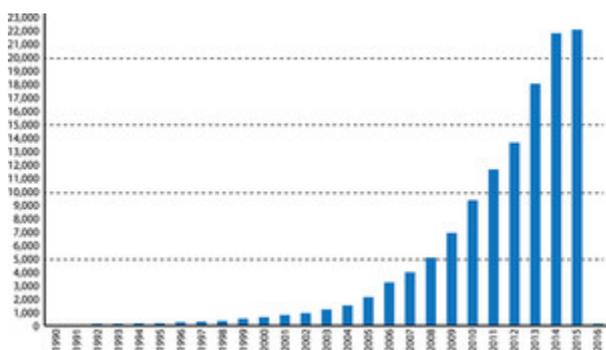
Keywords: resilience, social-ecological, development, transformation, sustainability

The last 15 years have seen an explosion of resilience research. A search on resilience at Google Scholar presents over 1.25 million hits today. About a million of those concern resilience and the environment (February 2016). Since 2000, the resilience and environment hits have increased about 14 times. In a search at ISI Web of Science (December 2015) there were, in year 2000, about 250 scientific publications on resilience in relation to the environment. In the last 15 years, the number has increased about 25 times, to well over 6,000 publications with more than a total of 120,000 citations across the natural sciences, social sciences, and humanities, and in interdisciplinary journals (Figure 1).

Resilience is a concept used in several areas and disciplines (e.g., Brand & Jax, 2007; Baggio et al., 2015). It has a strong tradition in psychology and human development (e.g., Brown & Westaway, 2011) and in ecology, ecosystem science, environmental management, and more recently social-ecological systems (e.g., Curtin & Parker, 2014; Desjardins et al., 2015; Folke, 2006). Now, resilience is found in studies on technology, networks, the welfare state, regional development, globalization, international relations, politics, organizational development,

social innovation, in management journals, education research, communication, building research, planning and urbanization, crime, health, risk and disaster management, national security, climate change, etc. Scholarly journals focusing on resilience have emerged—*Resilience: International Policies, Practices and Discourses* (Routledge), *International Journal of Disaster Resilience in the Built Environment* (Emerald) and *Ecology and Society: Integrative Science for Resilience and Sustainability*, published by the Resilience Alliance.

Resilience thinking has become part of practice, policy and business across the world, ranging from poverty alleviation to political frameworks and business strategies to anticipate and respond to change and crisis, not only to survive, but also to evolve. For example, resilience thinking has played a central role in the governance of the Great Barrier Reef in Australia and, in assessments of the future of the Arctic. The Global Resilience Partnership, convened by The Rockefeller Foundation, USAID, and Sida, Sweden, aims to help millions in Africa and Asia build more resilient futures. Resilience thinking is part of stewardship of diverse landscapes and seascapes, from water managers and farmers to municipalities and urban planners (e.g., Andersson et al., 2014; Harrison et al., 2014; Lengnick, 2015; Sellberg et al., 2015; Walker & Salt, 2012). In the 100 resilient cities collaboration, the focus has been on the capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and develop no matter what kinds of chronic stresses and acute shocks they experience. In the Transition Towns movement, resilience thinking has been used as an organizing principle by communities to challenge the status quo and to design and shape alternative futures (Brown, 2014). New collaborations for building resilience have emerged, like the global flood resilience alliance initiated by an insurance company, or the Resilience Action Initiative of several multinational enterprises (Kupers, 2014) focusing on practical action to deal with turbulent times in the context of food, water, energy and climate and to strengthen the adaptive capacity of their own operations in the communities they interact with and depend upon. In 2008, the World Resources Institute published, with United Nations Development Program (UNDP), United Nations Environment Program (UNEP), and the World Bank, the report “Roots of Resilience: Growing the Wealth of the Poor.” The UN-High Level Panel on Global Sustainability produced for the Rio+20 event in 2012 the report “Resilient People, Resilient Planet: A Future Worth Choosing.” The World Economic Forum’s Global Risks 2013 report focused on resilience, and “Resilient Dynamism” was the theme of the Forum’s 2013 annual meeting. These reflect but a handful of examples. Resilience is widely spread.



[Click to view larger](#)

**Figure 1.** The resilience and environment explosion in research. The graph presents the number of annual citations attributed to resilience in relation to the environment (environmental studies, environmental sciences, ecology). The number has increased from less than 100 citations in year 1995 to more than 20,000 citations in 2014 and 2015, respectively (based on ISI Web of Science, Dec. (2015).

Here, the focus is on resilience and the environment in relation to development and in particular on the evolution and spread of resilience thinking in this context (e.g., Folke et al., 2010; Walker & Salt, 2006). Resilience thinking emerged from the discovery, based on observation, that living systems have multiple basins of attraction (Holling, 1973). It has developed into an approach for understanding complex adaptive systems, and it serves as a platform for interdisciplinary and transdisciplinary research with an emphasis on social-ecological systems (e.g., Levin et al., 2013). Social-ecological systems are *intertwined systems of people and nature embedded in the biosphere*, the thin fragile layer of life around planet Earth (e.g., Berkes & Folke, 1998; Folke et al., 2011). The biosphere connection is a central observation that has to be visible in work on

resilience and social-ecological systems if sustainability

is to be taken seriously.

## What Is Resilience?

In some fields, the term resilience has been used in a narrow sense to refer to the return rate to equilibrium upon a perturbation. Others tend to interpret resilience as bouncing back after a disturbance, or recovery time, or recovery to what you were before in more general terms. In this way of looking at the world, there is often an implicit focus on trying to resist change and control it to maintain stability. The resilience approach of Resilience thinking is much richer. It deals with complex adaptive system dynamics and true uncertainty and how to learn to live with change and make use of it. Resilience thinking is the focus of this article.

In popular terms, resilience is having the capacity to persist in the face of change, to continue to develop with ever changing environments. Resilience thinking is about how periods of gradual changes interact with abrupt changes, and the capacity of people, communities, societies, cultures to adapt or even transform into new development pathways in the face of dynamic change. It is about how to navigate the journey in relation to diverse pathways, and thresholds and tipping points between them. In resilience thinking, adaptation refers to human actions that sustain development on current pathways, while transformation is about shifting development into other emergent pathways and even creating new ones.

Deliberate transformation involves breaking down the specific resilience of the old and building the resilience of the new (Folke et al., 2010). Specified resilience concerns resilience of what to what (Carpenter et al., 2001) and also for whom (Brown, 2014; Lebel et al., 2006; Robards et al., 2011). General resilience is for the unknown and the unknowable (Kates & Clark, 1996; Peterson, Carpenter, & Brock, 2003; Polasky, de Zeeuw, & Wagener, 2011), for having the capacity to deal with complexity, uncertainty, and surprise (Biggs, Bleckner, et al., 2012; Carpenter, Arrow, et al., 2012; Walker, Abel, et al., 2009). General resilience provides sources of memory, flexibility, options, and innovations for transformation and can help turn a crisis into an opportunity (e.g., Gunderson & Holling, 2002; Nykvist & von Heland, 2014).

## Early Work on Resilience and the Environment

Resilience as a concept in relation to the environment, or more specifically to ecosystems, was proposed by Holling (1973) as a way to understand the capacity of ecosystems to absorb change (reviewed by e.g., Desjardins et al., 2015; Gunderson, 2000) or more specifically, how to persist developing in the original state subject to disturbances and changing conditions (Holling, 1973).

Holling introduced resilience in the context of multiple stability domains or multiple basins of attraction in ecosystems, a radical idea at that time (Folke, 2006). His discovery of multiple basins of attraction in ecosystem dynamics challenged the, at that time, dominant stable-equilibrium view of ecosystems. He investigated how ecosystems relate to random events and heterogeneity of temporal and spatial scales and defined resilience as persistence of relationships within a system, as a measure of the ability of systems to absorb changes of state variables, driving variables, and parameters, and still persist (Holling, 1973).

The early days of resilience thinking draw on empirical observations of ecosystem dynamics often interpreted in mathematical models. Hence, inductive observations and empirical work led to the formulation of resilience as a feature of dynamic systems. Classic early work include, for example, Ludwig, Jones, and Holling (1978) and Walker, Ludwig, Holling, and Peterman (1981), some of which are compiled in Gunderson, Allen, and Holling (2009). The pioneering interdisciplinary volume *Sustainable Development of the Biosphere*, edited by Clark and Munn (1986) included Holling's (1986) classic chapter developing the theoretical basis for resilience dynamics emerging from the comparison of the ecosystem studies. In that chapter, the Adaptive Cycle of system development was introduced.

The multi-basins of attraction and resilience as the science of surprise became the theoretical foundation for the work, with active adaptive management of ecosystems where Buzz Holling, Carl Walters, Bill Clark, and colleagues mobilized a series of studies of large scale ecosystems subject to management (Clark et al., 1979; Holling, 1978; Holling & Chambers, 1973; Walters, 1986; Walters & Hilborn, 1978; Walters & Holling, 1990). The adaptive management process allowed for comparative analyses of the theoretical foundations of ecosystems behavior and ecosystems management. The conceptual underpinnings of adaptive management are simple; there will always be inherent uncertainty and unpredictability in the dynamics and behavior of complex systems, as a result of non-linear interactions among components and emergence, yet management decisions must still be made, and whenever possible, learning should be incorporated into management (e.g., Allen et al., 2011).

The resilience approach began early to influence work and discussions in fields outside ecology like anthropology, ecological economics, environmental psychology, human geography, and the management literature (reviewed in e.g., Abel & Stepp, 2003; Davidson-Hunt & Berkes, 2003; Folke, 2006; Scoones, 1999).

The Beijer Institute of the Royal Swedish Academy of Sciences was restarted in 1991, with a focus on the interface of ecology and economy. In the diverse research programmes of the Institute, resilience appeared and reappeared as a central feature for understanding complex system dynamics (e.g., Costanza et al., 1993). The volume *Biodiversity Loss* (Perrings et al., 1995) presented an ecological primer on functional diversity, regime shifts, and ecosystem services in an ecosystem resilience and cross-scale context (Holling et al., 1995; see also Elmqvist et al., 2003; Folke et al., 1996; Hughes et al., 2007; Lundberg & Moberg, 2003; Nyström et al., 2000; Peterson et al., 1998). Several papers as part of the Biodiversity program (e.g., Gadgil et al., 1993; Hammer et al., 1993; Perrings et al., 1992; Walker, 1993) and a recognized paper on economic growth (Arrow et al., 1995) incorporated resilience as a significant feature for human and environmental interactions (see also Levin et al., 1998). Holling and colleagues released the innovative book *Barrier and Bridges to the Renewal of Ecosystems and Institutions* in 1995 (Gunderson et al., 1995). The Beijer Institute program property rights and the performance of natural systems (Hanna et al., 1996) generated the Berkes and Folke (1998) volume *Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience*, one of the first volumes focusing on social-ecological systems and resilience thinking (e.g., Curtin & Parker, 2014; Ostrom, 1999).

As a reflection of the significance of a resilience lens for understanding complex social-ecological systems, the research program The Resilience Network was initiated through a collaboration of the Beijer Institute (Mäler and Folke) and University of Florida (Holling and Gunderson), a program that engaged pioneering resilience thinkers and that triggered a lot of interesting and path breaking work on resilience including the rich *Panarchy* volume (Gunderson & Holling, 2002), a volume on the significance of non-linear dynamics and regime shifts in economics—*The Economics of Non-Convex Ecosystems* (Dasgupta & Mäler, 2004) and the Berkes, Colding, and Folke (2003) book, *Navigating Social-Ecological Systems: Building Resilience for Complexity and Change*,

emphasizing the challenge of governing dynamic interactions between gradual and abrupt changes in social-ecological systems. This book presented a major synthesis of resilience challenges for social-ecological systems (Folke et al., 2003).

The Resilience Network later developed into the Resilience Alliance (RA), founded in 1999, with a coherent group of researchers oriented toward common intellectual goals who worked together at the fringe of scientific understanding (Parker & Hackett, 2012). The RA has contributed insights on resilience in complex social-ecological systems (e.g., Chapin et al., 2009; Janssen, 2002; Norberg & Cumming, 2008; Peterson, 2000; Walker & Salt, 2006), developed resilience thinking (e.g., Carpenter et al., 2001; Folke, 2006; Nelson et al., 2007; Quinlan et al., 2015; Walker & Salt, 2006), and also linked it to development agendas (e.g., Brown, 2016). For example, Elinor Ostrom, engaged on the Beijer Institute Board and later on the Stockholm Resilience Centre Board, became part of the Resilience Alliance, inspired by resilience thinking and the work on social-ecological systems (Ostrom, 1999, 2007, 2009). Ostrom's discussions at the Beijer Institute with Brian Walker and others on functional diversity and redundancy in ecosystem dynamics and regime shifts (e.g., Elmqvist et al., 2003; Peterson et al., 1998; Walker, 1992) inspired her book on institutional diversity (Ostrom, 2005).

Major syntheses on resilience and regime shifts in ecosystems were published (e.g., Bellwood et al., 2004; Carpenter, 2003; Folke et al., 2004; Scheffer et al., 2001). Resilience work expanded from adaptively managing ecosystems (e.g., Curtin & Parker, 2014; Gunderson & Pritchard, 2002) to adaptively governing complex social-ecological systems (e.g., Armitage et al., 2007, 2009; Folke et al., 2005), bringing in the role of institutions, organizations, networks, and agencies in this context (e.g., Adger, 2000; Berkes, 2009; Bodin & Crona, 2009; Crona & Bodin, 2006; Dietz et al., 2003; Galaz, 2005; Lebel et al., 2006; Olsson et al., 2004; Tompkins, 2005; Westley et al., 2006), social learning elements and knowledge systems (e.g., Berkes et al., 2000; Chapin et al., 2006; Fazey et al., 2007; Forbes et al., 2009; Olsson & Folke, 2001; Pahl-Wostl, 2007), ancient cultures (Hegmon et al., 2008; Redman & Kinzig, 2003), and political and power dimensions of sustainability (e.g., Adger, Brown, & Tompkins, 2005; Gelcich et al., 2006; Michon, 2011).

As indicated through the large number of publications and citations in the introduction, the resilience concept has spread, and this is not the place to review the large and expanding literature (e.g., Baggio et al., 2015; Brand & Jax, 2007; Brown & Westaway, 2011; Desjardins et al., 2015; Janssen, 2007; Meerow & Newell, 2015; Pu & Qiu, 2016; Xu & Marinova, 2013), close to an impossible task. But, resilience is influencing the environmental sciences from agriculture to oceans, as well as global, environmental, and climate change reflected in the IPCC Reports (e.g., O'Brien et al., 2012) and employed in risk and disaster management (e.g., Berkes, 2007; Djalante et al., 2013; McSweeney & Coomes, 2011; Tidball et al., 2010; Tidball & Stedman, 2012). Resilience thinking is raised in the development literature and in diverse ontologies and epistemologies of the social sciences and the humanities (e.g., Barrett & Constas, 2014; Bourbeau, 2015; Chandler, 2014; Crepin et al., 2012; Ebbesson & Hey, 2013; Hall & Lamont, 2013; Hamel & Välikangas, 2003; Hegmon et al., 2008; Hobman & Walker, 2015; Lorenz, 2013; Lyon & Parkins, 2013; Marston, 2015; Plieninger & Bieling, 2012; Redman, 2005; Robards et al., 2011; Simmie & Martin, 2010; Sjöstedt, 2015; Weichselgartner & Kelman, 2015), and with diverse reactions, from excitement to those that oppose the approach for diverse reasons (reviewed by e.g., Brown, 2014; Cretney, 2014; Stone-Jovicich, 2015).

After all, respect for pluralism (e.g., Norgaard, 1989), epistemological agility (the capacity to work productively across knowledge domains) (McWilliam, 2009), and an open mind capable of moving out of and dynamically modifying one's pre-analytic vision (e.g., Costanza, 2001) are assets with the potential to augment collective

understanding of complex social-ecological challenges. Attempts to integrate diverse perspectives or incorporate all dimensions into one unitary approach runs the risk of undermining the intellectual wealth and dialogues necessary to meet the challenges of the globally intertwined Anthropocene (e.g., Arora-Jonsson, 2016; Bousquet et al., 2015). Resilience thinking serves as one useful lens among many to ask questions, learn, and improve understanding of social-ecological systems.

## **Current Definition of Resilience Thinking—Integrating Resilience, Adaptability, Transformability**

Resilience reflects the ability of people, communities, societies, and cultures to live and develop with change and with ever-changing environments. It is about cultivating the capacity to sustain development in the face of change, incremental and abrupt, expected and surprising (Folke, 2006). The resilience approach emphasizes that social-ecological systems need to be managed and governed for flexibility and emergence rather than for maintaining stability (e.g., Carpenter, Brock, et al., 2015; Peterson, Cumming, & Carpenter, 2003). Hence, resilience, as in focus here, is a dynamic concept concerned with navigating complexity, uncertainty and change across levels and scales (e.g., Berkes et al., 2003; Cash et al., 2006; Cumming et al., 2013) on a human dominated planet (e.g., Lubchenco, 1998; Steffen et al., 2007).

*Resilience is about persisting with change* on the current path of development (stability domain or basin of attraction), adapting, improving, and innovating on that path. It is about having the capacity to continue to learn, self-organize, and develop in dynamic environments faced with true uncertainty and the unexpected, like steering a vessel in turbulent waters (e.g., Olsson et al., 2006).

But, sometimes navigation leads to induced isolation and intensification of particular paths and to traps that are difficult to get out of (e.g., Holling & Meffe, 1996; Sterner et al., 2006). The resilience of the system has become too robust and rigid (e.g., Allison & Hobbs, 2004; Cumming et al., 2014; Janssen & Scheffer, 2004; Steneck et al., 2011; Österblom et al., 2011). In such situations the challenge is to reduce or even break resilience of the current system to enable shifts away from the current pathway(s) into new ones, into alternative basins of attraction (Carpenter & Brock, 2008; Enfors, 2013; Marshall et al., 2012; Walker, Abel, et al., 2009). Sometimes those shifts may be smooth, other times revolutionary. As resilience declines, it takes progressively smaller disturbances to push the system into a different regime, or basin of attraction (Scheffer & Carpenter, 2003). Such regime shifts are at the core of resilience thinking (e.g., Biggs, Blenckner, et al., 2012; Rocha et al., 2015).

*Resilience* is 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, & therefore identity, that is, the capacity to change in order to maintain the same identity, i.e. resilience is a dynamic concept focusing on how to persist with change (Folke et al., 2010; Walker et al., 2004), how to evolve with change.

*Adaptability* refers to human actions that sustain development on current pathways. Adaptation is a process of deliberate change in anticipation of or in reaction to external stimuli and stress (Nelson et al., 2007). Adaptation and adaptive capacity of people, communities, and societies are concepts in use in global environmental change in general and in climate change in particular (e.g., Engle, 2011; Smit & Wandel, 2006; Wise et al., 2014) with overlap with resilience thinking. The adaptability concept in resilience thinking captures the capacity of people in a social-ecological system to learn, combine experience and knowledge, innovate, and adjust responses and institutions to changing external drivers and internal processes. Adaptability has been defined as “the capacity of actors in a system to influence resilience” (Walker et al., 2004) and is about adapting within critical social-

ecological thresholds. Adaptability is central to persistence. It helps turn changes and surprises into opportunities; hence, it is an important part of social-ecological resilience (Berkes et al., 2003; Nelson et al., 2007).

*Transformability* is about shifting development into new pathways and even creating novel ones. It is about the having the ability to cross thresholds and move social-ecological systems into new basins of attractions, into new, emergent, and often unknown development trajectories (e.g., Marshall et al., 2012; Walker, Abel, et al., 2009). Such ability draws on sources of resilience from levels and scales other than the one in focus for the transformation of the existing system. Crises can open up space for transformations, for new ways of thinking and operating. Here, experiences can be revitalized, recombined for novelty, and can help navigate the arising opportunities (e.g., Folke et al., 2009; Gunderson & Holling, 2002). Transformability has been defined as “the capacity to create a fundamentally new system when ecological, economic, or social structures make the existing system untenable” (Folke et al., 2010; Walker et al., 2004).

Transformability and transformation trajectories are the subject of growing interest (e.g., Future Earth) and literature (e.g., Chapin et al., 2010; Geels & Kemp, 2006; Leach et al., 2012; Loorbach, 2007; O’Brien et al., 2012; Olsson et al., 2014; Westley et al., 2011). Some scholars see transformation as the consequence of societal collapse, and others see the capacity to actively transform as an essential property of long-lasting functioning social-ecological systems (Feola, 2015). There are several different ways of approaching transformations (e.g., Fischer-Kowalski & Rotmans, 2009; Kates et al., 2012; Moore et al., 2014; O’Brien, 2012; Park et al., 2012; Pelling, 2011). All concepts of transformation recognize that transformative processes are characterized by discontinuities, thresholds, or tipping points and do not generally proceed smoothly; therefore, these cycles or phases represent attempts to make sense (Westley et al., 2006) of the complex behavior of social-ecological systems rather than strictly defining features of transformation (Feola, 2015).

The resilience approach to transformations is less about planning and controlling and more about preparing for opportunity or creating conditions of opportunity for navigating the transformations (Chapin et al., 2010). The resilience approach allows the new identity of the social-ecological system to emerge through interactions of individuals, communities, and societies, and through their interplay with the biosphere within and across scales (e.g., Cumming & Collier, 2005; Folke et al., 2010; Sendzimir et al., 2008). It concerns encouraging arenas for safe-to-fail experimentation, facilitating different transformative experiments at small scales and allowing cross-learning and new initiatives to emerge and spread across levels and scales, constrained only by avoiding trajectories undesirable from a sustainability perspective, especially those with known or suspected thresholds that challenge the capacity of the biosphere to sustain societal development and human well-being (Biggs et al., 2015; Westley et al., 2011). Enhancing resilience of the new stability domain is part of the transformation strategy (Chapin et al., 2010). The transformability insights of resilience thinking have largely emerged from case studies of social-ecological systems and human behavior in the real world (e.g., Enfors, 2013; Gelcich et al., 2010; Marshall et al., 2012; Olsson et al., 2004, 2006, 2008; Sendzimir et al., 2008).

Resilience, whether for adaptability or transformability, operates and needs to be addressed across levels and scales (Gunderson & Holling, 2002). Shifting pathways or basins of attractions at one level or scale does not take place in a vacuum. Any transformation draws on resilience from multiple scales and diverse sources of actors, organizations, and institutions, recombining experience and knowledge, learning with change, turning crises into windows of opportunity, and allowing space for, or even governing transformations for innovative pathways in tune with the resilience of the biosphere (Folke et al., 2010). Hence, in addition to emergence, resilience thinking emphasizes that humanity is embedded within the biosphere and that any attempt that takes sustainability seriously

will require sustainability transformations, with stewardship that operates in synergy with the biosphere foundation (Folke et al., 2011). Sustainability transformations seem to be necessary to achieve a just society that thrives within planetary boundaries and a biosphere resilient for humanity (O'Brien, 2012; Westley et al., 2011).

## Resilience, Complex Adaptive Social-Ecological Systems, and Sustainability Science

To many, the resilience approach is a subset of sustainability science (e.g., Anderies et al., 2013; Takeuchi et al., 2014). Vulnerability research also has strong links to sustainability science (e.g., Turner, Kasperson, et al., 2003), and there are differences and similarities with resilience thinking (e.g., Miller et al., 2010; Turner, 2010). Sustainability science is defined by the problems it addresses rather than by the disciplines it employs. A core focus of sustainability science is on transitions toward sustainability, including improving society's capacity to use the earth in ways that simultaneously meet the needs of a much larger but stabilizing human population, that sustain the life support systems of the planet, and that substantially reduce hunger and poverty (Clark, 2007; Matson et al., 2016).

Berkes and Folke (1998) started to use the concept of social-ecological systems as an integrated approach of *humans-in-nature* and related the concept to resilience. In this approach, the social refers to the human dimension of people, communities, societies in its diverse facets (e.g., economic, political, institutional, cultural), and the ecological to the biosphere—the thin layer around planet Earth where there is life, human life included. They pointed out that, in the social-ecological approach, the “the delineation between social and natural systems is artificial and arbitrary” (Berkes & Folke, 1998, p. 4). In essence, the social-ecological approach emphasizes that people, communities, economies, societies, and cultures are embedded parts of the biosphere and shape ecosystems, from local to global scales, from the past to the future. At the same time, people, communities, economies, societies, and cultures are fundamentally dependent on the capacity of the biosphere to sustain human development (Folke et al., 2011). It represents a *biosphere-based sustainability science* with resilience thinking as a central ingredient.

Baggio, Brown, and Hellebrandt (2015), in their citation network analysis of resilience, found that “the social-ecological systems field stands out as an emerging interdisciplinary arena where resilience can effectively act as a bridging concept and facilitate a discussion of dynamics of complex systems within varied contexts, informed by diverse perspectives, to provide potentially innovative theoretical and applied insights” (Baggio et al., 2015, p. 8).

Biggs et al. (2015) define resilience of a social-ecological system as the capacity of a social-ecological system to sustain human well-being in the face of change, both by buffering shocks and by adapting or transforming in response to change.

To understand the dynamics of intertwined social-ecological systems, taking into account that the very nature of systems changes over time (e.g., Carpenter, Brock, et al., 2015), complex adaptive systems come increasingly into focus (e.g., Holland, 1992; Levin, 1998; Norberg & Cumming, 2008). Social-ecological systems are complex adaptive systems. Complex adaptive systems possess critical thresholds, multiple drivers of change, and reciprocal feedbacks between social and ecological components (Levin et al., 2013).

## Resilience and Complex Adaptive Social-Ecological Systems

Many recurring environmental and natural resource challenges tend to be reinforced by the lack of recognition that ecosystems and the social systems that use and depend on them are intimately linked (Biggs et al., 2015; Norgaard, 1994; Reyers et al., 2013; van der Leeuw & Aschan-Leygonie, 2005). It is the feedback loops amongst them, as interdependent social-ecological systems, that determine their overall dynamics (Bots et al., 2015; Carpenter, Brock, et al., 2015; Fischer et al., 2015; Folke et al., 2002, 2010; Ostrom, 2009). In fact, they have been linked for a long time (e.g., Ellis, 2015). Theoretical and empirical analyses show how intertwined social-ecological systems are more than the sum of the ecological or the social or their combination, and they provide new explanations of regime shifts and tipping points (e.g., Bodin & Tengö, 2012; Hentati-Sundberg et al., 2015; Lade et al., 2013, 2015; Liu et al., 2007).

The resilience approach, as part of understanding the complex systems (e.g., Cillier, 2008; Holland, 1995), emphasizes that systems of humans and nature exhibit non-linear dynamics, thresholds, uncertainty, and surprise, and in particular, how periods of gradual change interplay with periods of rapid change, and how such dynamics interact across temporal and spatial scales (e.g., Berkes et al., 2003; Gunderson & Holling, 2002). Complex systems have multiple attractors, and there may be shifts from one attractor on a certain pathway to a new attractor and a contrasting pathway (stability domain or basin of attraction). Sharp shifts take place in ecosystems that stand out of the blur of fluctuations around trends and that may have different causes (e.g., Scheffer, 2009; Scheffer & Carpenter, 2003). The likelihood of such shifts increases with loss of resilience (e.g., Scheffer et al., 2001). During the last decades, it has become clear that human actions cause such shifts by altering resilience and disturbances (e.g., Biggs, Blenckner, et al., 2012; Folke et al., 2004; Schoon & Cox, 2012), as illustrated by a growing set of examples of both ecosystems and social-ecological systems (Rocha et al., 2015), and even by large-scale reorganizations like historical shifts from foraging to farming (Ullaha et al., 2015). The Regime Shifts DataBase provides examples of different types of regime shifts that have been documented. The database focuses specifically on regime shifts that have large impacts on ecosystem services and therefore on human well-being. Hence, in resilience thinking, social and ecological systems are intertwined, exhibiting emergent properties, and they can exist in qualitatively different states or basins of attraction.

Human as agents in social-ecological systems shape emergent structures in different ways based on their cultural systems. Geertz (1973) presents culture as a historically transmitted pattern of meanings embodied in symbols, a system of inherited conceptions expressed in symbolic forms by means of which humans communicate, perpetuate, and develop their knowledge about and their attitudes toward life. Cultural systems consist of concepts linked in complicated ways that can form consistent world views, can contain inconsistencies, and may or may not accurately model the properties of a social-ecological system. Consequently, human influence will differ, depending on cultural systems (Trosper, 2005). Deep cultural identities or cultural resilience may both constrain and be essential for adaptation or transformation (e.g., Rotarangi & Stephenson, 2014; Walker, Abel, et al., 2009; von Heland & Folke, 2014). The apparent stability and integrity of institutions and other social phenomena is not inherent, but an illusion created by the choice of a scale of observation that is shorter than the time over which the complex dynamics of the social-ecological system plays out (van der Leeuw & Aschan-Leygonie, 2005). Humans as agents operate in diverse social and cultural contexts that are all embedded part of the biosphere and that, consequently, will shape the biosphere in complex and different ways in continuous coevolution (e.g., Norgaard, 1994).

In complex adaptive systems, agents interact and connect with each other often in unpredictable and unplanned ways, but from such interaction broader scale patterns with new properties emerge, which then feeds back on the system and influences the interactions of the agents (e.g., Lansing & Kremer, 1993; Levin et al., 2013). Hence, the properties of complex adaptive systems change because of the interplay between the adaptive responses of the parts and the emergent properties of the whole that then feed back to the parts (e.g., Levin et al., 2013). The resilience of individuals, groups and communities is tightly coupled to this interplay and the emergent properties of the whole.

Since complex adaptive systems portray radically disproportional causation (i.e., small causes do not always produce small effects) or nonlinearity, they may depict periodic and chaotic dynamics, multiple basins of attraction, and potentially irreversible regime shifts (e.g., Biggs et al., 2009; Biggs, Blenckner, et al., 2012; Norström et al., 2009). Multiple slow and fast drivers of change make it difficult to predict when such dramatic changes will occur and to pinpoint cause-and-effect mechanisms (e.g., Hughes et al., 2013; Scheffer et al., 2012). Living with such complexity and change is facilitated by collaborative and adaptive approaches to management and by governance of the biosphere with decision-making subject to high degrees of uncertainty and with continuous learning as an important feature (e.g., Folke et al., 2005; Ludwig et al., 2001).

## Resilience of People or Planet in Development?

In resilience thinking and social-ecological systems research people are viewed as part of the planet, as part of the biosphere; consequently, development issues, whether for poverty alleviation, reduced inequality, or diverse aspects of power are embedded in a biosphere context. But it has to be stressed that even if a social-ecological systems may seem to be on a sustainable biosphere pathway for human well-being, actions to improve resilience on that pathway may benefit resilience of some and undermine resilience and increase vulnerability of others (e.g., Leach et al., 2010; Lebel et al., 2006). In contrast, actions aimed at increasing resilience in individuals, communities, and nations as the core focus may reinforce unsustainable pathways, undermine biosphere resilience, and challenge sustainability (e.g., Arrow et al., 1995; Westley et al., 2011). Determining when resilience is on a desirable or undesirable path, and for whom, is an inherently value-laden, subjective, and political question, a question that, if sustainability is in focus, needs to be connected to human well-being as part of the biosphere. From this perspective, sustainable development for humanity needs to be guided by approaches based on epistemologies and ontologies of development that appreciate the human-biosphere relationship.

Although on the table, issues of distribution, inequality, and diverse aspects of power and politics in their own right were not the core in the emergence of resilience thinking. Rather, they were incorporated as part of analyses of complex adaptive social-ecological systems, reflected in the abundant resilience work on agency, actors, participation, diverse knowledge systems, learning, coproduction, adaptive management, social networks, collective action, institutions, stewardship, social-ecological innovation, transformation, and multi-level and adaptive governance of social-ecological systems. Issues of inequality and diverse aspects of power and politics in social-ecological systems and sustainability are explicitly addressed through collaboration across knowledge domains and in the continuous evolution of resilience thinking (e.g., Boonstra, 2016; Crona & Bodin, 2010; Enfors, 2013; Fischer et al., 2015; Lebel et al., 2006; Michon, 2011; Raudsepp-Hearne, Peterson, & Bennett, 2010; Robards et al., 2011; Smith & Stirling, 2010; Stone-Jovicich, 2015). In this context, Brown (2016) argues that resilience can help understand and respond to the challenges of the contemporary age, challenges characterized by high uncertainty, globalized and interconnected systems, increasing disparities and limited choices.

Resilience is increasingly having an impact on development research, from the individual, to community, to society as a whole. Development research with a resilience connection is becoming abundant, theoretically and empirically (e.g., Béné et al., 2016; Hall & Lamont, 2013). For example, development resilience has been defined as “the capacity over time of a person, household, or other aggregate unit to avoid poverty in the face of various stressors and in the wake of myriad shocks. If and only if that capacity is and remains high over time, then the unit is resilient” (Barrett & Constanas, 2014). The theory of development resilience approaches poverty dynamics of individuals in a way that makes the literature of economics and social science on poverty and poverty traps more explicit when considering issues of risk, dynamics, and appreciation of ecological feedback. This definition of resilience at the microscale puts the individual agents and their basic rights and aspirations for improved living conditions in focus.

There is work on poverty, adaptability, food security, social protection, adaptive capacity, and resilience of individuals, households, and groups in relation to ecosystem and environmental change in general, and climate change in particular (e.g., Andrew et al., 2007; Berkes & Jolly, 2001; Boyd et al., 2008; Cinner et al., 2015; Davies et al., 2013; Kelly & Adger, 2000; Marshall & Stokes, 2014; Nayak et al., 2014; Thomas & Twyman, 2005). For example, Béné, Headey, Haddad, and von Grebmer (2016) in their review of resilience in food security, nutrition, and development, employ the definition of resilience as used here (see above) in relation to short-term humanitarian interventions, climate change projects, and long-term development programs. They argue that resilience results from the combination of absorptive capacity leading to persistence, adaptive capacity, leading to incremental adjustments/changes and adaptation, and transformative capacity leading to transformational responses.

Community resilience has surfaced as a vibrant area (e.g., Amundsen, 2012; Berkes & Ross, 2013). For example, it has been found that communities can seize on the window of opportunity created by climate-induced shocks to generate sustained social-ecological improvement, implying that management should foster local capacities for endogenous institutional change to enhance community resilience to climate shocks (McSweeney & Coomes, 2011). Norris, Stevens, Pfefferbaum, and Wyche (2008), argue that community resilience emerges from four primary sets of adaptive capacities, namely economic development, social capital, information and communication, and community competence; as a whole, they help provide community capacity to deal with change, like disasters. Robards and Alessa (2004) note that Arctic communities have maintained their existence over time by their ability to recognize gradual or rapid changes and to adapt to those, rather than to any specific outcomes of a change. Resilience as a dynamic concept is reflected in the definition of community resilience as the existence, development, and engagement of community resources by community members to thrive in an environment characterized by change, uncertainty, unpredictability, and surprise and adapt and occasionally transform (Margis, 2010). It is about planning for not having a plan, which requires flexibility, decision-making skills, and trusted sources of information that function in the face of unknowns (Norris et al., 2008). The cross-scale dimension of community and social resilience, and in relation to globalization processes, is gaining attention and striking the right “balances” between communities and their scalar interactions and dependencies on global economic processes is key for social-ecological resilience (e.g., Crona et al., 2015; Scholes et al., 2013; Wilson, 2012).

Brown and Westaway (2011) provide an excellent resilience review synthesizing knowledge on agency, adaptive capacity, and resilience across human development, well-being, and disasters literature to provide insights to support more integrated and human-centered approaches to understanding environmental change. They find first, that there has been a shift away from the notion that central concepts of resilience thinking—adaptive capacity,

resilience, and well-being—can be objectively measured by a set of quantifiable indicators to a much more complex, nuanced view that understands them as comprising subjective, relational as well as objective aspects. Second, that there is a growing recognition that dynamic systems approaches—including ecological or social-ecological in its broadest sense—and cross-scale perspectives are necessary. Third, in the human development, well-being, and disasters fields, there is a move away from deficit models to ideas about assets and capacities (Brown & Westaway, 2011).

Brown (2016), in the recent book on resilience in development, argues that a resilience-based approach to development might radically transform responses to climate change, to the dilemmas of managing ecosystems, and to rural and urban poverty in the developing world. She elaborates the notion of everyday forms of resilience as part of a new development agenda with three core components: resistance, rootedness, and resourcefulness. Resistance puts concerns for politics and power at the heart of resilience, how new spaces for change can be opened up and how positive transformation might be shaped and mobilized. Rootedness is about locating culture and place, both as a biophysical environment and context and as identity and attachment, while also working at and across multiple scales. Resourcefulness concerns capacities, knowledge, innovation, and learning, and how resources can be accessed and used in response to change.

In a classic paper, Adger (2000) compares social and ecological resilience and defines social resilience as the ability of groups or communities to cope with external stresses and disturbances as a result of social, institutional, political, and environmental change. Hall and Lamont (2013) present a systems-oriented definition of social resilience that, very much like resilience thinking, emphasizes adaptation or transformation over return to an earlier state. They are interested, in general terms, in the understanding of how individuals, communities, and societies secure their well-being in the face of its challenges, how well-being is secured by groups of people more or less bound together in an organization, class, group, community, or country. More specifically, they see social resilience in dynamic terms as the achievement of well-being even when that entails significant modifications to behavior or to the social frameworks that structure and give meaning to behavior. Well-being in this context refers broadly to physical and psychological health, material sustenance, and the sense of dignity and belonging that comes with being a recognized member of the community or society. Hence, in focus is the capacity of individuals or groups to secure favorable outcomes (material, symbolic, emotional) under new circumstances and, when necessary, by new means. Consequently, social resilience is used to denote an outcome in which members of a group sustain their well-being in the face of challenges to it (Hall & Lamont, 2013).

The additional argument from resilience thinking is that well-being of individuals, communities, and societies is tightly coupled to the capacity of the biosphere to sustain it. This is an obvious fact in a situation when the scale, connectivity, spread, and speed of human actions shape the dynamics of the biosphere and the earth system as a whole (e.g., Folke et al., 2011; Steffen et al., 2007, 2015; Turner et al., 1990).

## Resilience and the Anthropocene

The scale of human actions and the speed, spread, and connectivity of globalization create new complex dynamics across levels and domains that play out in new ways (e.g., Biggs et al., 2011; Homer-Dixon et al., 2015; Walker, Barrett, et al., 2009; Young et al., 2006). Interconnections of humans in a globalized society can propagate and cascade across countries and regions (e.g., Adger et al., 2009; Eriksson et al., 2015; Galaz et al., 2011; Liu et al.,

2013; Österblom et al., 2015), shaping landscapes, seascapes, the well-being of people and social-ecological systems worldwide (e.g., Berkes et al., 2006; Fairhead et al., 2012; Galaz, 2014; Holling, 1995; Hughes et al., 2003; Keys et al., 2016; Lazarus, 2014; Merrie et al., 2014). These interactions and feedbacks are not just global but cross-scale (e.g., Crona et al., 2015; Deutsch et al., 2007; Galaz et al., 2015; Lambin & Meyfroidt, 2011; Thyresson et al., 2011); the speed of them may even make the global operate faster than the local. It implies that studies and action of the local should not only focus on endogenous relations, but also account for and prepare for living with and collaborating with influences from other levels, be they political decisions, economic drivers, transnational companies, migration policies, altered rainfall patterns, or climate change (e.g., Folke et al., 2011; Rockström, Falkenmark, Folke, et al., 2014; Walker, Barrett, et al., 2009). Some of those may be slow creeping influences, others abrupt and surprising (e.g., Hansen et al., 2012; Homer-Dixon et al., 2015; Hughes et al., 2013). It is a truly intertwined social-ecological planet we are living on.

The great acceleration of the human dimension on earth, in terms of people and activities, and diverse reasons behind it from the discovery of fossil fuels to power dynamics between nations and regions, has placed humanity in a new terrain as a major force in shaping biosphere processes. This scale increase in relation to the life-supporting biosphere (e.g., Arrow et al., 1995; Boulding, 1966; Daily & Ehrlich, 1992; Odum, 1989) has moved humanity into a proposed new geological era—the Anthropocene—the age of man (Brondizio et al., 2016; Steffen et al., 2007). Resilience and regime shifts are part of the challenges humanity is facing in the Anthropocene, from regional tipping points (e.g., Lenton et al., 2008; Österblom & Folke, 2015) to possible shifts at planetary scales (e.g., Barnosky et al., 2012; Steffen et al., 2011) and assessments of dynamic planetary boundaries in this context (Rockström et al., 2009; Steffen et al., 2015). It has been suggested that to sustain the planet in a Holocene-like state (the geological era of the last 11 thousand years of favorable condition for development of human civilizations), transformations at local and regional scales will be needed (e.g., Steffen et al., 2015). In other words, to sustain resilience of favorable biosphere conditions for humanity as a whole, there will have to be transformations toward new ways of development, not just incremental tweaking of business as usual on current development pathways (e.g., Folke et al., 2010; Westley et al., 2011). Views on good or bad pathways of transformations differ and often depend on values and political positions on issues like globalization, power inequalities, and distribution conflicts of development, uneven environmental degradation included (e.g., Hornborg et al., 2007). A resilience approach would emphasize flexibility and opportunity of diverse pathways, and keeping options open to be able to shift between those, in a manner that remains within the safe operating space of the biosphere, and with prosperity and abundance for humans in collaboration with biosphere resilience.

## Capturing Resilience

Resilience as an approach for analyzing, understanding, and managing change in social-ecological systems is different from resilience as a property of a social-ecological system (e.g., Biggs et al., 2015; Nelson et al., 2007). Resilience as a system property is, as discussed earlier, the capacity of a specific social-ecological system to continually self-organize and adapt in the face of ongoing change in a way that sustains the system in a certain stability domain or development path. When analysing resilience as a system property in relation to regime shifts it is useful to consider resilience of what to what (Carpenter et al., 2001). Biggs, Schlüter, and Schoon (2015) see resilience as the capacity of a social-ecological system to sustain human well-being in the face of change, by persisting and adapting or transforming in response to change. A central challenge in this context is the capacity of social-ecological systems to continue to provide key ecosystem services that underpin human well-being in the face of unexpected shocks as well as gradual, on-going change (e.g., Bennett et al., 2009; Biggs et al., 2015; Carpenter, Mooney, et al., 2009).

How can resilience as a property be captured? There is search for metrics and indicators of resilience, not an easy task since social-ecological systems are complex adaptive systems, moving targets continuously developing and evolving. It is important to avoid the trap of developing metrics of what is easy to measure rather than what is important (Carpenter, Folke, et al., 2009). Developing a set of indicators of resilience as a system property may block the deeper understanding of system dynamics needed to apply resilience thinking and navigate a turbulent world (e.g., Quinlan et al., 2015). Therefore, resilience as a system property should not be reduced to a simple metric, but different types of metrics and indicators need to be used and combined to capture facets of resilience and help guide management and governance. A snapshot of approaches is presented below.

In recent years, progress has been made in understanding signals of regime shifts and critical transitions. Resilience research has clarified how phenomena such as flickering, critical slowing down, increased autocorrelation, decreasing recovery rates, and increased variance can serve as “early warnings” of loss of resilience and of regime shifts in nature, from ecosystems to the dynamics of the planet as a whole (e.g., Dakos et al., 2008; Scheffer et al., 2012), and how such signals relate to management, human behavior, and the safe-operating spaces of ecosystem regimes (e.g., Biggs et al., 2009; Crepin et al., 2012; Scheffer et al., 2015; Schill et al., 2015). The safe-operating space was proposed in relation to zones of uncertainty with potential thresholds of critical processes at the global level, or planetary boundaries, where loss of resilience and regime shifts may challenge essential favorable conditions for human life on earth (Rockström et al., 2009).

Several studies aim at developing resilience indicators in relation to regime shifts in diverse ecosystems, often with a focus on the interplay of fast and slow variables and feedback management (e.g., Carpenter et al., 2001; Nyström et al., 2008; Nyström et al., 2012; Graham et al., 2013; Jouffray et al., 2015), and how those are connected in dynamic landscapes and seascapes and across scales, as in spatial resilience (e.g., Bengtsson et al., 2003; Cumming, 2011; Nyström and Folke, 2001; Sundström et al., 2014) or with broader processes like rainfall patterns (Gordon et al., 2008; Keys et al., 2012) or fisheries and global seabird populations (Cury et al., 2011). There are efforts aimed at capturing resilience in economic terms and models in relation to regime shifts (e.g., Crepin et al., 2012; de Zeeuw, 2014; Mäler and Li, 2010; Polasky, de Zeeuw, & Wagener, 2011; Richter and Dakos, 2015; Walker et al., 2010).

Others are developing metrics of change in ecosystem services and natural capital in relation to social-ecological systems and human well-being, with connections to resilience (e.g., Guerry et al., 2015; Raudsepp-Hearne, Peterson, Tengö, et al., 2010). Some focus on measuring resilience at the individual level, and often in relation to poverty (e.g., Barrett & Constanas, 2014), or on understanding how communities can transform out of poverty traps (e.g., Enfors, 2013) or how to break resilience of one development path and transform to another and build resilience on that path (e.g., Moore et al., 2014). Turning crises into windows of opportunity, and aligning actors and networks across multilayers of governance at critical moments, seem to be significant in such social-ecological regime shifts (e.g., Chapin et al., 2010; Olsson et al., 2004; Schultz et al., 2015).

There are those who concentrate on adaptation and adaptive capacity in relation to change with links to resilience thinking (e.g., Wise et al., 2014), and there have been attempts to identify surrogates for resilience (e.g., Carpenter et al., 2005) as well as sources of resilience (e.g., Adger, Hughes, et al., 2005; Adger et al., 2011; Goulden et al., 2013). The latter concept is closely related to the theoretical concept of “remember” for reorganization (Gunderson & Holling, 2002), which has inspired studies on social-ecological memory as critical for building resilience, as well as the role of biocultural refugia as pockets of social-ecological memory in times of change (Barthel et al., 2010, 2013; Barthel & Isendahl, 2013). The role of memory and sources of resilience are addressed in work on

cultural landscapes and with links to sense-of-place and deep identities as resilience features in adaptations and transformations (e.g., Adger et al., 2013; Crane, 2010; Fernandez-Gimenez, 2015; Lyon, 2014; Plieninger & Bieling, 2012; Tidball et al., 2010; Tidball & Stedman, 2012; Turner, Davidson-Hunt, & O'Flaherty, 2003). There is work on cultural resilience, often in relation to indigenous groups and cultures subject to change, emphasizing elements (e.g., resilience pivots, ancestral contracts) of a social-ecological system that endure despite adaptation or even transformation of other elements and in doing so support the persistence of the system's distinctive identity (e.g., Forbes, 2013; Rotarangi & Stephenson, 2014; von Heland & Folke, 2014).

Another critical feature concerns the role of functional biodiversity and functional groups of species in ecosystem resilience and regime shifts (e.g., Bellwood et al., 2004; Folke et al., 2004; Hughes et al., 2007; Peterson et al., 1998; Walker et al., 1999), as well as the role of agency and diverse actors and actor groups in social-ecological system dynamics and their adaptations and transformations (e.g., Folke et al., 2003, 2005; Westley et al., 2013) as functional diversity and social actor strategies are increasingly linked (e.g., Diaz et al., 2011). A critical concept for resilience management in this context is response diversity, defined as the diversity of responses to environmental change among species contributing to the same ecosystem function (Elmqvist et al., 2003).

Response diversity has been found to be particularly important for renewal and reorganization in ecosystems following change (e.g., Hughes et al., 2007; Jansson & Polasky, 2010; Laliberte et al., 2010; Winfree & Kremen, 2009). The concept is gaining interest in research on social-ecological systems, including livelihood options, across multiple levels (e.g., Leslie & McCabe, 2013) and in governance and management of urban landscapes and ecosystem services (e.g., Andersson et al., 2007; Colding, 2007).

There will always be tension between the degree of simplification that measurement and metrics demand and the point at which these make the system understanding fragmented and their implementation meaningful (Quinlan et al., 2015). Resilience assessments aim at a deep understanding of social-ecological system dynamics, recognizing that resilience is a dynamic property shaped by many different processes of interacting fast and slow variables, including the larger context and cross-scale dynamics in which the social-ecological system is embedded (e.g., Scholes et al., 2013) as well as unintentional changes of unforeseen dynamics (e.g., Quinlan et al., 2015). Building on a theoretical foundation and case study history, resilience assessments offer guidance toward understanding the social-ecological dynamics of a given place and time with the objective to inform management (e.g., Mitchell et al., 2014; Walker & Salt, 2012). The practice of resilience assessments has illustrated the value of a shared process of learning and understanding complex social-ecological systems dynamics (Quinlan et al., 2015). Resilience assessments have been tested and applied in a number of settings, like catchment and mountain management in Australia and the United States, municipalities and urban areas in Canada and Sweden, or pasture management in Afghanistan (e.g., Haider et al., 2012; Liu, 2014; Lockwood et al., 2014; Nemeč et al., 2013; Sellberg et al., 2015; Walker, Abel et al., 2009). An updated framework based on the Resilience Alliance's Workbook for practitioners (Resilience Alliance, 2010), originally developed by Lance Gunderson, Ann Kinzig, Allyson Quinlan, and Brian Walker, combines the focus on understanding complex adaptive social-ecological systems in the new Anthropocene context with guidance on the identification and use of indicators to measure and monitor over time (O'Connell et al., 2015).

## **Resilience and Stewardship of Social-Ecological Systems: From the Local to the Global**

Urbanization is a major driver of the Anthropocene (e.g., Seto et al., 2012), with well over half of the human population currently living in urban areas. There is a tendency to become mentally disconnected from the

biosphere in urban settings (e.g., Gomez-Baggethun & Barton, 2013). There is a lot of work on urban resilience (e.g., Andersson, 2006; Elmqvist et al., 2013; Leichenko, 2011; Marcus & Colding, 2014; Pickett et al., 2004; Pu & Qiu, 2016). Green spaces and their stewards and stewardship is an exciting area of resilience research in urban social-ecological systems (e.g., Andersson et al., 2007; Colding, 2007; Colding & Barthel, 2013; Colding et al., 2006; Connolly et al., 2014; Ernstson et al., 2008; Wilkinson, 2012; Wilkinson et al., 2010), often with emphasis on how to reconnect people in cities and urban development to the biosphere and essential ecosystem services in relation to resilience (e.g., Andersson et al., 2014; Gomez-Baggethun & Barton, 2013; Jansson, 2013; McPhearson et al., 2015).

In the globally intertwined social-ecological system, everyone is everyone else's backyard, and cities both shape and are dependent on huge areas across the planet for ecosystem support (e.g., Grimm et al., 2008; Folke et al., 1997), for water, food, and other ecosystem services (e.g., Bennett et al., 2014; Rist et al., 2014; Rockström, Falkenmark, Allan, et al., 2014; Troell et al., 2014). It will be in the self-interest of urban dwellers in the Anthropocene to create incentives for stewardship of their supporting ecosystems, or social-ecological systems often far away from city borders and that secure the basis of city life.

The stewardship challenge is of central focus in resilience thinking (e.g., Chapin et al., 2009; Folke et al., 2003; and see Fig. 2), from early work on adaptive management to regime shifts and adaptive governance of social-ecological systems and ecosystem services. Ecosystem services are a key emergent outcome of social-ecological interactions (e.g., Reyers et al., 2013; von Heland & Folke, 2014). But, the stewardship challenge makes clear that, although people's management is critical, it is not sufficient to focus only on the human dimension if sustainability is central, since sustainability requires governance systems and development practices in tune with biosphere capacity (e.g., Guerry et al., 2015; Folke et al., 2011). Therefore, ecological knowledge and understanding of ecosystem processes and dynamics, of the natural capital, and the social-ecological interplay of such processes and dynamics is a prerequisite in this context (e.g., Berkes et al., 2003; Berkes & Folke, 1998). Skill sets for stewardship of natural capital range from abilities of experimenting, learning and gaining ecological knowledge and experience on the ground (e.g., Chapin et al., 2009; King, 2008; Olsson et al., 2004) to capturing and accounting for broader scale biophysical processes like rainfall patterns or climate dynamics (e.g., Keys et al., 2012; Rockström, Falkenmark, Folke, et al., 2014) in the governance and management of social-ecological systems. Supported by proper institutions and incentives such skills help build identity, meaning, pride and dignity in being a steward of the ecological foundation for human well-being in collaboration with the biosphere.

Work on distribution, equality, fairness, justice, and power are of major significance in the resilience and stewardship context, but seldom the core focus in their own right. They enter resilience thinking as significant features of understanding and governing social-ecological dynamics for biosphere stewardship, human well-being, and sustainability (e.g., Fischer et al., 2015; Lebel et al., 2006; Robards et al., 2011).

The challenge of biosphere stewardship and resilience was raised in the Millennium Ecosystem Assessment and through the engagement of resilience-oriented scholars in the development of the assessment, especially in the case studies of the sub-global assessment as well as the scenarios work (e.g., Capistrano et al., 2006; Reid et al., 2006). Here, the role of people as part of ecosystem dynamics and stewardship of dynamic landscapes and seascapes and their ecosystem services were in the forefront as was the challenge of bringing in diverse knowledge systems as part of stewardship and governance across institutions at multiple levels (Carpenter, Mooney, et al., 2009).



[Click to view larger](#)

**Figure 2.** Examples of stewardship strategies for dealing with uncertainty and change, and strategies to transform from unsustainable social-ecological pathways to potentially more favorable ones (modified from Chapin et al., 2010).

Schultz & Lundholm, 2010; Tengö et al., 2014). Social-ecological inventories have been used to set such processes in motion (e.g., Baird et al., 2014; Schultz et al., 2007) and the concept ecological solidarity highlights the intertwined interplay of social-ecological systems (Mathevet et al., 2010; Mathevet et al., 2016).

Resilience work has studied institutions and governance structures that allow for ecosystem-based management in some detail and has focused especially on the emergence of flexible governance arrangements that have shifted and transformed human activities towards adaptive governance of social-ecological systems (e.g., Folke et al., 2005; Chaffin et al., 2014; Huitema et al., 2009; Karpouzoglou et al., 2016). This work has been particularly well developed as regards the stewardship of landscapes and seascapes (e.g., Cosens & Williams, 2012; Gelcich et al., 2010; Olsson et al., 2004, 2006, 2008). Several studies illustrate the role of institutional entrepreneurs in this context (e.g., Ernstson et al., 2010; Folke et al., 2005; Meijerink & Huitema, 2010; Merrie & Olsson, 2014; Rosén & Olsson, 2013; Westley et al., 2013). In these situations, actors start interacting and connecting with each other, often in unpredictable and unplanned ways, and from such interactions broader scale patterns with new properties emerge, which then feedback on the social-ecological system and influence the actors and their interactions (Levin et al., 2013). Such a dynamic interplay of actors, social networks, bridging organizations, and diverse and multilevel institutions—continuously learning with change—are found to be significant features of social-ecological system dynamics, often emerging in relation to crisis (perceived or real) and opening windows of opportunity for change towards stewardship of ecosystem services (e.g., Bodin & Crona, 2009; Crona & Parker, 2012; Hahn et al., 2006; Olsson et al., 2004, 2008; Österblom & Folke, 2013; Pahl-Wostl et al., 2007; Rathwell & Peterson, 2012; Schultz et al., 2015). Such “adaptive waves” of moving up scales of social-ecological systems occur both inadvertently and deliberately in response to both rapid and gradual changes and may lead to increased resilience on a higher governance scale (e.g., Luthe & Wyss, 2015; Olsson et al., 2007).

There is a lot of work on management of ecosystem resilience for ecosystem services (e.g., Moberg & Folke, 1999; Scheffer et al., 2015), with adaptive management as a way of experimenting, learning, and developing understanding for stewardship (e.g., Allen et al., 2011). The literature on adaptive co-management of ecosystem and complex social-ecological systems is also rich (e.g., Armitage et al., 2007, 2009; Berkes, 2009; Cinner et al., 2012). There is resilience work on the role of indigenous and local knowledge systems as experienced-based knowledge for ecosystem management of social-ecological systems, including shocks (e.g., Berkes et al., 2000; Forbes et al., 2009; Gomez-Baggethun & Barton, 2013; Rumbach & Foley, 2014) and how to connect diverse knowledge systems, the role of coproduction of knowledge and collaborative learning among communities and stakeholders, and their significance in stewardship of ecosystem services (e.g., Bohensky & Maru, 2011; Boyd et al., 2013; Daw et al., 2015; Fazey et al., 2007; Goldstein, 2012; Mathevet et al., 2011; Raymond et al., 2010; Reyers et al., 2015;

However, restructuring current institutions and governance systems for resilience is no small task and the challenge in relation to social-ecological systems and resilience is subject to a growing literature (e.g., Dietz et al., 2003; Schlüter & Herrfahrdt-Pähle, 2011; Sjöstedt, 2015; Young, 2010, 2011). Such restructuring raises issues of representative democracy, accountability, and legitimacy in governance (e.g., Cosens, 2013; Hahn, 2011). There is also the problem of fit between institutions, governance, and social-ecological systems (e.g., Galaz et al., 2008; Ekstrom & Young, 2009; Treml et al., 2015) and how institutions and governance systems can handle change and stability simultaneously (e.g., Duit et al., 2010; Green et al., 2013; Voss & Bornemann, 2011) including cascading changes of an intertwined world (e.g., Galaz et al., 2011). Global governance challenges are raised in relation to planetary boundaries and stewardship (e.g., Biermann et al., 2012; Galaz, Biermann, et al., 2012) and the emergence of new forms of institutions for governance of the biosphere (e.g., Galaz, Crona, et al., 2012).

There is also work on resilience in relation to legal structures, principles, and processes (e.g., Garmestani et al., 2013), as well as core concepts of the rule of law (e.g., Ebbesson, 2010) and the making of normative choices of public interest, public and private responsibilities, and individual rights, including equality before the law and non-discrimination (e.g., Ebbesson & Hey, 2013). West and Schultz (2015) conclude that the European Court of Human Rights constitutes an important site of learning for governance of social-ecological systems, because it situates knowledge and experience of environmental change in the context of discussions about the relative rights, duties, and responsibilities of social actors, facilitating the mutually adaptive evolution of truth and justice across scales. Work on new forms of social contracts, emphasizing the dynamics, links, and complexity of social-ecological systems is also part of the resilience discourse (O'Brien et al., 2009). As stated by Cosens (2013), the recognition of the complexity in the social-ecological system, coupled with a growing realization of the complete dependence of the human race on the ability of the ecological system to serve it, requires reform of the administrative state to allow society to responsibly respond to the challenge of managing human interaction with ecosystems.

Scenario planning is a forward looking approach that aims to articulate multiple alternative futures in a way that spans a key set of critical uncertainties, using qualitative and quantitative methods and data (e.g., Carpenter et al., 2006; Peterson, Cumming, & Carpenter, 2003; Swart et al., 2004) and engaging diverse stakeholder in participatory processes for stewardship of social-ecological systems subject to change (e.g., Enfors et al., 2008; Carpenter, Booth, et al., 2015; Oteros-Rozas et al., 2015; Plieninger et al., 2013). Scenario work is an important part of the Future Earth Programme on Ecosystem Change and Society (PECS), a program with a strong focus on social-ecological systems, resilience, and stewardship of ecosystem services in dynamic landscapes and seascapes, operating in the context of the challenges of the Anthropocene (Carpenter, Folke, et al., 2012; Fischer et al., 2015).

## Expect the Unexpected

In their article, "Expecting the Unexpected," Kates and Clark (1996) make clear that in a complex and intertwined world, surprise is to be expected. Resilience thinking has been characterized as the science of surprise. Surprise—when perceived reality departs qualitatively from expectation—is strongly shaped by underlying metaphors, models, and belief systems (Holling, 1986).

Surprise is not just about shocks and extreme events but also about slower changing and less visible dynamics (e.g., Gunderson, 2001). We are not always aware of the sands shifting beneath our feet as events change the character of the times in diffuse ways (Hall & Lamont, 2013). Resilience thinking is about the interplay of incremental and abrupt change, of slow and fast variables in complex adaptive systems and how it plays out in

uncertain, surprising and often unpredictable ways (e.g., Carpenter, Folke, et al., 2009; Gunderson & Holling, 2002). Resilience thinking is about true uncertainty and unknown unknowns and not just about probabilities around risk and uncertainty (Carpenter et al., 2006; Carpenter, Folke, et al., 2009; Polasky, Carpenter, et al., 2011).

As suggested by Holling (1986), contemporary challenges of the globally intertwined social-ecological systems are indeed system challenges, complex, unpredictable, nonlinear, with discontinuous behavior in space and time, and where causes, at times simple, are always multiple. The cross-scale challenges are a reflection of decadal to centennial accumulation of human influences on air and oceans and transformations of landscapes, causing sudden changes in fast environmental variables, and affecting the health of people, the vitality of societies, and the essential life-support functions of the biosphere (e.g., Clark & Munn, 1986; Gunderson et al., 1995). Indeed, the complex interplay of human actions shaping biosphere capacity has placed humanity in a novel situation of interactions of social-ecological systems across scales that are expressed in new, intertwined, and often turbulent and surprising ways (e.g., Biggs et al., 2011; Galaz et al., 2011; Homer-Dixon et al., 2015; Steffen et al., 2015; Walker, Barrett, et al., 2009), affecting people and places in disparate ways. The situation presents major challenges and opportunities for adaptation and transformation (e.g., Adger et al., 2011; Biermann et al., 2012; Galaz, Crona, et al., 2012; Hill & Engle, 2013; Westley et al., 2011).

Solutions that focus on knowledge of small parts or that assume constancy or stability of fundamental relationships, tend to be pathological, producing policy and science with a sense of certainty leading to rigid and unseeing institutions and increasingly vulnerable social-ecological systems (Gunderson et al., 1995; Holling, 1986; Holling & Meffe, 1996). It may even be possible that recent advances and widespread availability of information may make people overconfident about the ability to anticipate and deal with surprise, thereby making people more vulnerable to it (Kates & Clark, 1996). The challenge is to anticipate change and surprise in a manner that does not lead to lock-in and loss of future options (e.g., Berkes et al., 2003; Boyd et al., 2015; Costanza et al., 2000).

Managing for resilience enhances the likelihood of sustaining development in a rapidly changing world where surprise is likely (e.g., Carpenter, Folke, et al., 2009; Chapin et al., 2009; Folke, 2006). When transformation is inevitable, resilient social-ecological systems contain the components needed for renewal and reorganization, reconnecting development to the biosphere for human well-being and sustainability (e.g., Boyd & Folke, 2012; Biggs et al., 2015; Folke et al., 2002).

Resilience-building management of the Anthropocene is flexible and open to learning. It attends to slowly changing, fundamental variables that create memory, legacy, diversity, and the capacity to innovate in both social and ecological components of the system. It also conserves, builds experience, and nurtures the diverse elements that are necessary to reorganize and adapt to novel, unexpected, and transformative circumstances. Thus, it increases the range of surprises with which a social-ecological system can cope (Folke et al., 2002) and may even serve to open windows-of-opportunity for societies to increase capacity to govern social-ecological change over the long-term (e.g., Kates & Clark, 1996; Luthe & Wyss, 2015).

Often, resilience is applied to challenges relating to particular aspects of a social-ecological system that might arise from a particular set of sources or shocks, referred to as specified resilience (Walker, Abel, et al., 2009). Specified resilience arises in response to the question “resilience of what to what?” (Carpenter et al., 2001) and for “whom” (e.g., Lebel et al., 2006). Becoming too focused on specified resilience to increase resilience of particular parts or dimensions of a social-ecological system to specific disturbances may cause the system to lose resilience in other ways. This observation is critical for e.g., disaster management or policies aimed at poverty alleviation (e.g., Berkes, 2007; Djalante et al., 2013). For example, the Pumpa social- ecological system of rice-paddy irrigation in

Nepal developed into a socially well-tuned institution for dealing with specific fluctuations of climate and hydrology, but in the process the governance structure for water management created vulnerability to long-term changes in climate and institutional arrangements (Cifdaloz et al., 2010).

In fact, it seem like governance and management aimed at reducing variance in flows of ecosystem services will lead to loss of resilience in social-ecological systems to changing conditions (Carpenter, Brock, et al., 2015). Hence, there are trade-offs between resilience of a social-ecological system to a small set of known kinds of disturbance versus the vast universe of unknown novel shocks (e.g., Carpenter, Folke, et al., 2009). Specified resilience approaches may be narrowing options for dealing with novel shocks and even increasing the likelihood of new kinds of instability (Carpenter, Brock, et al., 2015). It seems like systems that become very robust to frequent kinds of disturbance necessarily become fragile in relation to infrequent kinds (e.g., Anderies, 2015; Folke et al., 2010).

## Enhancing Resilience in General

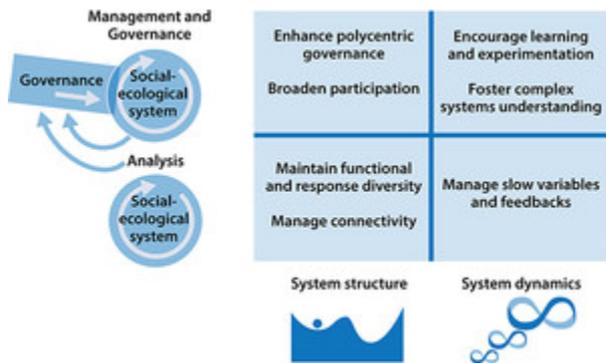
General resilience is a more broad-spectrum type of resilience for building capacity of social-ecological systems to adapt or transform in response to the unknown. It is about resilience to all kinds of shocks, including extreme, novel and non-computable ones (e.g., Carpenter, Folke, et al., 2009). Among conditions that enable general resilience are diversity, modularity, openness, reserves, feedbacks, nestedness, monitoring, leadership, and, trust (Carpenter, Arrow, et al., 2012). General resilience is about having the capacity to deal with ongoing diffuse gradual change, with true uncertainty and surprise. General resilience envisions a central role in buying insurance against surprises generated by complex intertwined social-ecological systems of the Anthropocene. But, as a public good it has a cost. How much general resilience is needed, in what dimensions, and how can long-term practices be woven into actions that also meet the immediate needs of people and ecosystems?

Based on empirical work and case studies, Folke, Colding, and Berkes (2003) proposed four key features of general resilience-building for adaptive capacity, features that interact across temporal and spatial scales and that seem significant for dealing with dynamics in social-ecological systems:

- Learn to live with change and uncertainty;
- Nurture diversity for reorganization and renewal;
- Combine different types of knowledge for learning; and
- Create opportunity for self-organization towards social-ecological sustainability.

The first emphasizes the significance of accepting uncertainty and surprise, taking advantage of change and crisis and having the capacity of turning change into opportunity for social-ecological development in tune with the biosphere. The second illuminates the importance of nurturing diversity for social-ecological resilience, recognizing that diversity is more than insurance against uncertainty and surprise. It also provides the bundle of components, and their history, that makes development and innovation following disturbance and crisis possible, components that are embedded in the social-ecological memory. The third is about the significance of peoples' knowledge, experience and understanding about ecosystem dynamics and their inclusion in management practice and institutions. The fourth brings these issues together in the context of self-organization, scale, governance, and external drivers, stressing the significance of the dynamic interplay between diversity and disturbance (Folke et al., 2003).

Biggs, Schlüter, et al. (2012, 2015) have identified a set of seven generic and policy-relevant principles for enhancing resilience of critical ecosystem services for human well-being in the face of disturbance and ongoing change in complex social-ecological systems. These principles are: (P1) maintain diversity and redundancy, (P2) manage connectivity, (P3) manage slow variables and feedbacks, (P4) foster an understanding of SES as complex adaptive systems (CAS), (P5) encourage learning and experimentation, (P6) broaden participation, and (P7) promote polycentric governance systems. Quinlan et al. (2015) divided the principles along two axes by whether they focus primarily on the resilience of a social-ecological system or its governance, and by whether they focus on resilience based on system structure or its dynamics, strategies that are complementary and can be combined (Figure 3).



*Click to view larger*

*Figure 3.* Principles for enhancing building in relation to the structure and dynamics of social-ecological systems and their analysis, management, and governance (modified from Quinlan et al., 2015).

Briefly summarized, the principles stress that (P1) high levels of diversity and redundancy, but not too high levels, tend to make social-ecological more resilient to change and provide options and flexibility for development; that (P2) connectivity needs to be managed for sources of resilience, for trust in networks, for new information etc., but that there is a tension between too much connectivity versus modularity in complex social-ecological systems operating across levels and scales; that (P3) where known, changes in slow variables and feedbacks should be monitored with governance systems that can respond in a timely manner and those supporting biosphere stewardship for ecosystem services and human well-being should be strengthened; that (P4) fostering complex adaptive system thinking entails uncertainty-tolerant cultures investigating potential non-linearities and thresholds, allowing for diverse knowledge and matching institutions and governance to complex adaptive system processes; that (P5) encouraging learning through experimentation and monitoring is essential for enabling adaptive responses; and it requires social capital, such that (P6) participation, and how it takes place, is facilitated, and the skills involved are key for learning, building social capital and collective action; and finally, that (P7) polycentricity of governance enables the other resilience enhancing principles. Their implementation involves clarification of goals and developing and monitoring relevant metrics for each principle, taking an integrative approach that builds on multiple knowledge systems, shifting away from exclusively managing for efficiency towards planning for uncertainty and surprise, creating spaces for spontaneous exploration, and building trust and social capital (Biggs et al., 2015).

Such principles, whether for resilience building, collective action dilemmas (e.g., Ostrom, 1990) or adaptive governance (e.g., Folke et al., 2005), should not be approached as end goals but rather as processes or mechanisms for generating conditions that allow for resolving collective-action challenges associated with multiple trade-offs in complex social-ecological systems. Such principles challenge the presumption that scholars can make simple, predictive models of social-ecological systems and deduce universal solutions, panaceas, to implement a certain principle (e.g., Biggs et al., 2015; Clarvis et al., 2015; Holling et al., 1998; Ostrom, 2007; Pahl-Wostl et al., 2012). Rather, they support reflection, learning and adaptation in search, for deep understanding of complex, multivariable, nonlinear, cross-scale, and changing social-ecological systems and how to relate this understanding for biosphere stewardship.

## Concluding Remarks

Resilience thinking is an integrative approach for dealing with the sustainability challenge. It is about cultivating the capacity to sustain development in the face of change, incremental and abrupt, expected and surprising, in relation to diverse pathways and thresholds and tipping points between them. Resilience thinking can be viewed as a subset of sustainability science and has a strong focus on complex adaptive and truly intertwined social-ecological systems of people, communities, economies, societies, and cultures interacting across spatial and temporal scales with ecosystems as part of the biosphere. The scale, speed, and connectivity of human actions in a globalized and intertwined world create new complex dynamics that play out in new, uncertain, and surprising ways, and differently for different people and places. Resilience of a social-ecological system refers to the capacity to develop and sustain human well-being in diverse contexts in the face of such change, both incremental and abrupt, but also through adapting or transforming in response to change.

Social-ecological systems are embedded in the biosphere. The biosphere connection is a central observation of resilience thinking, an observation that has to be explicit in work on resilience and social-ecological systems if sustainability is to be taken seriously. Confronted with planetary boundaries, it will become central for human well-being in the urbanized 21st century to create incentives for transformation of human actions towards stewardship of complex adaptive social-ecological systems in ways that are in tune with the resilience of the biosphere. Well-being and development ultimately rests on biosphere capacity.

## Suggested Readings

Béné, C., Headey, D., Haddad, L., & von Grebmer, K. (2016). Is resilience a useful concept in the context of food security and nutrition programmes? Some conceptual and practical considerations. *Food Security*, 8(1), 123–138.

Find this resource:

Berkes, F., Colding, J., & Folke, C. (Eds.). (2003). *Navigating social-ecological systems: Building resilience for complexity and change*. Cambridge, U.K.: Cambridge University Press.

Find this resource:

Biggs, R., Schlüter, M., & Schoon, M. L. (Eds.). (2015). *Principles for building resilience: Sustaining ecosystem services in social-ecological systems*. Cambridge, U.K.: Cambridge University Press.

Find this resource:

Brown, K. (2016). *Resilience, development and global change*. London: Routledge.

Find this resource:

Carpenter, S. R., Folke, C., Norström, A., Olsson, O., Schultz, L., Agarwal, B., et al. (2012). Program on ecosystem change and society: An international research strategy for integrated social-ecological systems. *Current Opinion in Environmental Sustainability*, 4, 134–138.

Find this resource:

Chapin III, F. S., Kofinas, G. P., & Folke, C. (Eds.). (2009). *Principles of ecosystem stewardship: Resilience-based natural resource management in a changing world*. New York: Springer.

Find this resource:

Folke, C., Carpenter, S. R., Walker, B. H., Scheffer, M., Chapin III, F. S., & Rockström, J. (2010). Resilience thinking: Integrating resilience, adaptability, and transformability. *Ecology and Society*, 15(4), 20.

Find this resource:

Folke, C., Jansson, Å., Rockström, J., Olsson, P., Carpenter, S. R., Chapin, F. S., et al. (2011). Reconnecting to the biosphere. *Ambio*, 40, 719–738.

Find this resource:

Gunderson, L. H., & Holling, C. S. (Eds.). (2002). *Panarchy: Understanding transformations in human and natural systems*. Washington, DC: Island Press.

Find this resource:

Marshall, N. A., Park, S. E., Adger, W. N., Brown, K., & Howden, S. M. (2012). Transformational capacity and the influence of place and identity. *Environmental Research Letters*, 7, 034022.

Find this resource:

McSweeney, K., & Coomes, O. T. (2011). Climate-related disaster opens a window of opportunity for rural poor in northeastern Honduras. *Proceedings of the National Academy of Sciences, USA*, 108, 5203–5208.

Find this resource:

Nelson, D. R., Adger, W. N., & Brown, K. (2007). Adaptation to environmental change: Contributions of a resilience framework. *Annual Review of Environment and Resources*, 32, 395–419.

Find this resource:

Norberg, J., & Cumming, G. (Eds.). (2008). *Complexity theory for a sustainable future*. New York: Columbia University Press.

Find this resource:

Quinlan, A. E., Berbes-Blazquez, M., Haider, L. J., & Peterson, G. D. (2015). **Measuring and assessing resilience: Broadening understanding through multiple disciplinary perspectives**. *Journal of Applied Ecology*, 53, 677–687.

Find this resource:

Rocha, J. C., Peterson, G. D., & Biggs, R. O. (2015). **Regime shifts in the Anthropocene: Drivers, risks, and resilience**. *PLoS ONE*, 10(8), e0134639.

Find this resource:

Stone-Jovicich, S. (2015). Probing the interfaces between the social sciences and social-ecological resilience: Insights from integrative and hybrid perspectives in the social sciences. *Ecology and Society*, 20(2), 25.

Find this resource:

Turner II, B. L. (2010). Vulnerability and resilience: Coalescing or paralleling approaches for sustainability science? *Global Environmental Change*, 20, 570–576.

Find this resource:

Walker, B., & Salt, D. (2006). *Resilience thinking*. Washington, DC: Island Press.

Find this resource:

Westley, F., Olsson, P., Folke, C., Homer-Dixon, T., et al. (2011). Tipping towards sustainability: Emerging pathways of transformation. *Ambio*, *40*, 762–780.

Find this resource:

## References

Abel, T., & Stepp, J. R. (2003). A new ecosystems ecology for anthropology. *Conservation Ecology*, *7*(3), 12.

Find this resource:

Adger, W. N. (2000). Social and ecological resilience: Are they related? *Progress in Human Geography*, *24*, 347–364.

Find this resource:

Adger, W. N., Barnett, J., Brown, K., Marshall, N., & O'Brien, K. (2013). Cultural dimensions of climate change impacts and adaptation. *Nature Climate Change*, *3*, 112–117.

Find this resource:

Adger, W. N., Brown, K., Nelson, D. R., Berkes, F., Eakin, H., Folke, C., et al. (2011). Resilience implications of policy responses to climate change. *WIREs Climate Change*, *2*, 757–766.

Find this resource:

Adger, W. N., Brown, K., & Tompkins, E. L. (2005). The political economy of cross-scale networks in resource co-management. *Ecology and Society*, *10*(2), 9.

Find this resource:

Adger, W. N., Eakin, H., & Winkels, A. (2009). Nested and teleconnected vulnerabilities to environmental change. *Frontiers in Ecology and the Environment*, *7*, 150–157.

Find this resource:

Adger, W. N., Hughes, T., Folke, C., Carpenter, S. R., & Rockström, J. (2005). Social-ecological resilience to coastal disasters. *Science*, *309*, 1036–1039.

Find this resource:

Allen, C. R., Pope, K. L., & Fontaine, J. J. (Eds.). (2011). Adaptive management for natural resources. *Journal of Environmental Management*, *92*, 1339–1428.

Find this resource:

Allison, H. E., & Hobbs, R. J. (2004). Resilience, adaptive capacity, & the “lock-in trap” of the Western Australian agricultural region. *Ecology and Society*, *9*(1), 3.

Find this resource:

Amundsen, H. (2012). Illusions of resilience? An analysis of community responses to change in northern Norway. *Ecology and Society*, *17*(4), 46.

Find this resource:

Anderies, J. M. (2015). Managing variance: Key policy challenges for the Anthropocene. *Proceedings of the National Academy of Sciences, USA*, *47*, 14402–14403.

Find this resource:

Anderies, J. M., Folke, C., Walker, B., & Ostrom, E. (2013). Aligning key concepts for global change policy: robustness, resilience, & sustainability. *Ecology and Society*, 18(2), 8.

Find this resource:

Andersson, E. (2006). Urban landscapes and sustainable cities. *Ecology and Society*, 11(1), 34.

Find this resource:

Andersson, E., Barthel, S., Borgström, S., Colding, J., Elmqvist, T., Folke, C., & Gren, Å. (2014). Reconnecting cities to the biosphere: Stewardship of green infrastructure and urban ecosystem services. *Ambio*, 43, 445–453.

Find this resource:

Andersson, E. A., Barthel, S. B., & Ahrne, K. (2007). Measuring social-ecological dynamics behind the generation of ecosystem services. *Ecological Applications*, 17, 1267–1278.

Find this resource:

Andrew, N. L., Bene, C., Hall, S. J., Allison, E. H., Heck, S., & Ratner, B. D. (2007). Diagnosis and management of small-scale fisheries in developing countries. *Fish and Fisheries*, 8, 227–240.

Find this resource:

Armitage, D., Berkes, F., & Doubleday, N. (Eds.). (2007). *Adaptive co-management: Collaboration, learning and multi-level governance*. Vancouver, British Columbia: University of British Columbia Press.

Find this resource:

Armitage, D. R., Plummer, R., Berkes, F., Arthur, R. I., Charles, A. T., Davidson-Hunt, I. J., et al. (2009). Adaptive co-management for social-ecological complexity. *Frontiers in Ecology and the Environment*, 7, 95–102.

Find this resource:

Arora-Jonsson, S. (2016). Does resilience have a culture? Ecocultures and the politics of knowledge production. *Ecological Economics*, 121, 98–107.

Find this resource:

Arrow, K., Bolin, B., Costanza, R., Dasgupta, P., Folke, C., Holling, C. S., et al. (1995). Economic growth, carrying capacity, & the environment. *Science*, 268, 520–521.

Find this resource:

Baggio, J. A., Brown, K., & Hellebrandt, D. (2015). Boundary object or bridging concept? A citation network analysis of resilience. *Ecology and Society*, 20(2), 2.

Find this resource:

Baird, J., Plummer, R., & Pickering, K. (2014). Priming the governance system for climate change adaptation: The application of a social-ecological inventory to engage actors in Niagara, Canada. *Ecology and Society*, 19(1), 3.

Find this resource:

Barnosky, A. D., Hadly, E. A., Bascompte, J., Berlow, E. L., Brown, J. H., Fortelius, M., et al. (2012). Approaching a state shift in Earth's biosphere. *Nature*, 486, 52–58.

Find this resource:

Barrett, C. B., & Constanas, M. A. (2014). Toward a theory of resilience for international development applications. *Proceedings of the National Academy of Sciences, USA, 111*, 14625–14630.

Find this resource:

Barthel, S., Crumley, C., & Svedin, U. (2013). Bio-cultural refugia: Safeguarding diversity of practices for food security and biodiversity. *Global Environmental Change, 23*, 1142–1152.

Find this resource:

Barthel, S., Folke, C., & Colding, J. (2010) Social-ecological memory in urban gardens: Retaining the capacity for management of ecosystem services. *Global Environmental Change, 20*, 255–265.

Find this resource:

Barthel, S., & Isendahl, C. (2013). Urban gardens, agriculture, & water management: Sources of resilience for long-term food security in cities. *Ecological Economics, 86*, 224–234.

Find this resource:

Bellwood, D., Hughes, T., Folke, C., & Nyström, M. (2004). Confronting the coral reef crisis. *Nature, 429*, 827–833.

Find this resource:

Béné, C., Headey, D., Haddad, L., & von Grebmer, K. (2016). Is resilience a useful concept in the context of food security and nutrition programmes? Some conceptual and practical considerations. *Food Security, 8*(1), 123–138.

Find this resource:

Bengtsson, J., Angelstam, P., Elmqvist, T., Emanuelsson, U., Folke, C., Ihse, M., et al. (2003). Reserves, resilience, & dynamic landscapes. *Ambio, 32*, 389–396.

Find this resource:

Bennett, E. M., Carpenter, S.R., Gordon, L. J., Ramankutty, N., Balvanera, P., Campbell, B., et al. (2014). Toward a more resilient agriculture. *Solutions, 5*(5), 65–75.

Find this resource:

Bennett, E. M., Peterson, G. D., & Gordon, L. J. (2009). Understanding relationships among multiple ecosystem services. *Ecology Letters, 12*, 1394–1404.

Find this resource:

Berkes, F. (2007). Understanding uncertainty and reducing vulnerability: Lessons from resilience thinking. *Natural Hazards, 41*, 283–295.

Find this resource:

Berkes, F. (2009). Evolution of co-management: Role of knowledge generation, bridging organizations and social learning. *Journal of Environmental Management, 90*, 1692–1702.

Find this resource:

Berkes, F. Colding, J., & Folke, C. (Eds.). (2003). *Navigating social-ecological systems: Building resilience for complexity and change*. Cambridge, U.K.: Cambridge University Press.

Find this resource:

Berkes, F., & Folke, C. (Eds.). (1998). *Linking social and ecological systems: Management practices and social mechanisms for building resilience*. Cambridge, U.K.: Cambridge University Press.

Find this resource:

Berkes, F., Folke, C., & Colding, J. (2000). Rediscovery of traditional ecological knowledge as adaptive management. *Ecological Applications*, *10*, 1251–1262.

Find this resource:

Berkes, F., Hughes, T. P., Steneck, R. S., Wilson, J. A., Bellwood, D. R., Crona, B., et al. (2006). Globalization, roving bandits, & marine resources. *Science*, *311*, 1557–1558.

Find this resource:

Berkes, F., & Jolly, D. (2001). Adapting to climate change: social-ecological resilience in a Canadian western Arctic community. *Conservation Ecology*, *5*(2), 18.

Find this resource:

Berkes, F., & Ross, H. (2013). Community resilience: Toward an integrated approach. *Society & Natural Resources*, *26*, 5–20.

Find this resource:

Biermann, F., Abbott, K., Andresen, S., Bäckstrand, K., Bernstein, S., Betsill, M. M., et al. (2012). Navigating the Anthropocene: Improving earth system governance. *Science*, *335*, 1306–1307.

Find this resource:

Biggs, D., Biggs, R., Dakos, V., Scholes, R. J., & Schoon, M. (2011) Are we entering an era of concatenated global crises? *Ecology and Society*, *16*(2), 27.

Find this resource:

Biggs, R., Blenckner, T., Folke, C., Gordon, L., Norström, A., Nyström, M., & G Peterson. (2012). Regime shifts. In A. Hastings & L. Gross (Eds.), *Encyclopedia in theoretical ecology* (pp. 609–616). Berkeley, CA: University of California Press.

Find this resource:

Biggs, R., Carpenter, S. R., & Brock, W. A. (2009). Turning back from the brink: Detecting and impending regime shift in time to avert it. *Proceedings of the National Academy of Sciences, USA*, *106*, 826–831.

Find this resource:

Biggs, R., Schlüter, M., Biggs, D., Bohensky, E. L., BurnSilver, S., Cundill, G., et al. (2012). Toward principles for enhancing the resilience of ecosystem services. *Annual Review of Environment and Resources*, *37*, 421–448.

Find this resource:

Biggs, R., Schlüter, M., & Schoon, M. L. (Eds.). (2015). *Principles for building resilience: sustaining ecosystem services in social-ecological systems*. Cambridge, U.K.: Cambridge University Press.

Find this resource:

Bodin, Ö., & Crona, B. I. (2009). The role of social networks in natural resource governance: What relational patterns make a difference? *Global Environmental Change*, *19*, 366–374.

Find this resource:

Bodin, Ö., & Tengö, M. (2012). Disentangling intangible social-ecological systems. *Global Environmental Change*, 22, 430–439.

Find this resource:

Bohensky, E. L., & Maru, Y. (2011). Indigenous knowledge, science, & resilience: What have we learned from a decade of international literature on “integration”? *Ecology and Society*, 16(4), 6.

Find this resource:

Boonstra, W. (2016). **Conceptualizing power to study social-ecological interactions**. *Ecology and Society*, 21(1), 21.

Find this resource:

Bots, P. W. G., Schlüter, M., & Sendzimir, J. (2015). A framework for analyzing, comparing, & diagnosing social-ecological systems. *Ecology and Society*, 20(4), 18.

Find this resource:

Boulding, K. E. (1966). The economics of the coming spaceship Earth. In H. Jarrett (Ed.), *Environmental quality in a growing economy* (pp. 3–14). Baltimore: Johns Hopkins University Press.

Find this resource:

Bourbeau, P. (2015). Resilience and international politics: Premises, debates, agenda. *International Studies Review*, 17, 374–395.

Find this resource:

Bousquet, F., Robbins, P., Peloquin, C., & Bonato, O. (2015). The PISA grammar decodes diverse human–environment approaches. *Global Environmental Change*, 34, 159–171.

Find this resource:

Boyd, E., Cornforth, R. J., Lamb, P. J., Tarhule, A., Lele, M. I., & Brouder, A. (2013). Building resilience to face recurring environmental crisis in African Sahel. *Nature Climate Change*, 3, 631–637.

Find this resource:

Boyd, E., & Folke, C. (Eds.). (2012). *Adapting institutions: Governance, complexity and social-ecological resilience*. Cambridge, U.K.: Cambridge University Press,

Find this resource:

Boyd, E., Nykvist, B., Borgström, S., & Stacewicz, I. A. (2015). Anticipatory governance for social-ecological resilience. *Ambio*, 44, S149–S161.

Find this resource:

Boyd, E., Osbahr, H., Ericksen, P., Tompkins, E., Lemos, M., & Miller, F. (2008). Resilience and “climatizing” development: Examples and policy implications. *Development*, 51, 390–396.

Find this resource:

Brand, F. S., & Jax, K. (2007). Focusing the meaning(s) of resilience: Resilience as a descriptive concept and a boundary object. *Ecology and Society*, 12(1), 23.

Find this resource:

Brondizio, E. S., O'Brien, K., Bai, X., Biermann, F., Steffen, W., Berkhout F., et al. (2016). **Re-conceptualizing the Anthropocene: A call for collaboration.** *Global Environmental Change*, 29, 318–327.

Find this resource:

Brown, K. (2014). Global environmental change I: A social turn for resilience? *Progress in Human Geography*, 38, 107–117.

Find this resource:

Brown, K. (2016). *Resilience, development and global change*. London: Routledge.

Find this resource:

Brown, K., & Westaway, E. (2011). Agency, capacity, & resilience to environmental change: Lessons from human development, well-being, & disasters. *Annual Review of Environment and Resources*, 36, 321–342.

Find this resource:

Capistrano, D., Samper, C., Lee, M. J., & Raudsepp-Hearne, C. (Eds.). (2006). *Ecosystems and Human Well-Being: Multiscale Assessments: Findings of the Sub-global Assessments Working Group*, Millennium Ecosystem Assessment Series. Washington, DC: Island Press.

Find this resource:

Carpenter, S. R. (2003). *Regime shifts in lake ecosystems: Pattern and variation*. Excellence in Ecology 15. Oldendorf, Germany: International Ecology Institute.

Find this resource:

Carpenter, S. R., Arrow, K. J., Barrett, S., Biggs, R., Brock, W. A., Crépin, A.-S., et al. (2012). General resilience to cope with extreme events. *Sustainability*, 4, 3248–3259.

Find this resource:

Carpenter, S. R., Bennett, E. M., & Peterson, G. D. (2006). Scenarios for ecosystem services: an overview. *Ecology and Society*, 11(1), 29.

Find this resource:

Carpenter, S. R., Booth, E. G., Gillon, S., Kucharik, C. J., Loheide, S., Mase, A. S., et al. (2015). Plausible futures of a social-ecological system: Yahara watershed, Wisconsin, USA. *Ecology and Society*, 20(2), 10.

Find this resource:

Carpenter, S. R., & Brock, W. A. (2008). Adaptive capacity and traps. *Ecology and Society*, 13(2), 40.

Find this resource:

Carpenter, S. R., Brock, W., Folke, C., van der Nees, E., & Scheffer, M. (2015). Allowing variance may enlarge the safe operating space for exploited ecosystems. *Proceedings of the National Academy of Sciences, USA*, 112, 14384–14389.

Find this resource:

Carpenter, S. R., Folke, C., Norström, A., Olsson, O., Schultz, L., Agarwal, B., et al. (2012). Program on Ecosystem Change and Society: An international research strategy for integrated social-ecological systems. *Current Opinion in Environmental Sustainability*, 4, 134–138.

Find this resource:

Carpenter, S. R., Folke, C., Scheffer, M., & Westley, F. (2009). Resilience: Accounting for the non-computable. *Ecology and Society*, 14(1), 13.

Find this resource:

Carpenter, S. R., Mooney, H. A., Agard, J., Capistrano, D., DeFries, R. S., Diaz, S., et al. (2009). Science for managing ecosystem services: Beyond the Millennium Ecosystem Assessment. *Proceedings of the National Academy of Sciences, USA*, 106, 1305–1312.

Find this resource:

Carpenter, S. R., Walker, B. H., Anderies, J. M., & Abel, N. (2001). From metaphor to measurement: Resilience of what to what? *Ecosystems*, 4, 765–781.

Find this resource:

Carpenter, S. R., Westley, F., & Turner, M. G. (2005). Surrogates for resilience of social-ecological systems. *Ecosystems*, 8, 941–944.

Find this resource:

Cash, D. W., Adger, W., Berkes, F., Garden, P., Lebel, L., Olsson, P., et al. (2006). Scale and cross-scale dynamics: Governance and information in a multilevel world. *Ecology and Society*, 11(2), 8.

Find this resource:

Chaffin, B. C., Gosnell, H., & Cosens, B. A. (2014). A decade of adaptive governance scholarship: Synthesis and future directions. *Ecology and Society*, 19(3), 56.

Find this resource:

Chandler, D. (2014). Beyond neoliberalism: Resilience, the new art of governing complexity. *Resilience*, 2, 47–63.

Find this resource:

Chapin, F. S. III, Carpenter, S. R., Kofinas, G. P., Folke, C., Abel, N., Clark, W. C., et al. (2010). Ecosystem stewardship: Sustainability strategies for a rapidly changing planet. *Trends in Ecology and Evolution*, 25, 241–249.

Find this resource:

Chapin, F. S. III, Kofinas, G. P., & Folke C. (Eds.). (2009) *Principles of ecosystem stewardship: Resilience-based natural resource management in a changing world*. New York: Springer.

Find this resource:

Chapin, F. S. III, Lovcraft, A. L., Zavaleta, E. S., Nelson, J., Robards, M. D., Kofinas, G. P., et al. (2006). Policy strategies to address sustainability of Alaskan boreal forests in response to a directionally changing climate. *Proceedings of the National Academy of Sciences, USA*, 103, 16637–16643.

Find this resource:

Cifdaloz, O., Regmi, A., Anderies, J. M., & Rodriguez, A. A. (2010). Robustness, vulnerability, & adaptive capacity in small-scale social-ecological systems: The Pampa irrigation system in Nepal. *Ecology and Society*, 15(3), 39.

Find this resource:

Cillier, P. (2008). Complexity theory as a general framework for sustainability science. In M. Burns & A. Weaver (Eds.), *Exploring sustainability science: A Southern African perspective*. Stellenbosch, South Africa: Sun Press.

Find this resource:

Cinner, J. E., Hutchery, C., Hicks, C. C., Daw, T. M., Marshall, N., Wamukota, A., & Allison, E. H. (2015). Changes in adaptive capacity of Kenyan fishing communities. *Nature Climate Change*, 5, 872–876.

Find this resource:

Cinner, J. E., McClanahan, T. R., MacNeil, M. A., Graham, N. A. J., Daw, T. M., Mukminin, A., et al. (2012). Comanagement of coral reef social-ecological systems. *Proceedings of the National Academy of Sciences, USA*, 109, 5219–5222.

Find this resource:

Clark, W. C. (2007). Sustainability science: A room of its own. *Proceedings of the National Academy of Sciences, USA*, 104, 1737–1738.

Find this resource:

Clark, W. C., Jones, D. D., & Holling, C. S. (1979). Lessons for ecological policy design: A case study of ecosystem management. *Ecological Modelling*, 7, 1–53.

Find this resource:

Clark W. C., & Munn, R. E. (Eds.). (1986). *Sustainable development of the biosphere*. Cambridge, U.K.: Cambridge University Press.

Find this resource:

Clarvis, M. H., Bohensky, E., & Yarime, M. (2015). Can resilience thinking inform resilience investments? Learning from resilience principles for disaster risk reduction. *Sustainability*, 7, 9048–9066.

Find this resource:

Colding, J. (2007). “Ecological land-use complementation” for building resilience in urban ecosystems. *Landscape and Urban Planning*, 81, 46–55.

Find this resource:

Colding, J., & Barthel, S. (2013). The potential of “Urban Green Commons” in the resilience building of cities. *Ecological Economics*, 86, 156–166.

Find this resource:

Colding, J., Lundberg, J., & Folke, C. (2006). Incorporating green-area user groups in urban ecosystem management. *Ambio*, 35, 237–244.

Find this resource:

Connolly, J. J. T., Svendsen, E. S., Fisher, D. R., & Campbell, L. K. (2014). Networked governance and the management of ecosystem services: The case of urban environmental stewardship in New York City. *Ecosystem Services*, 10, 187–194.

Find this resource:

Cosens, B. A. (2013). Legitimacy, adaptation, & resilience in ecosystem management. *Ecology and Society*, 18(1), 3.

Find this resource:

Cosens, B. A., & Williams, M. K. (2012). Resilience and water governance: Adaptive governance in the Columbia River basin. *Ecology and Society*, 17(4), 3.

Find this resource:

Costanza, R. (2001). Visions, values, valuation, & the need for an ecological economics. *BioScience*, 51, 459–468.

Find this resource:

Costanza, R., Daly H, Folke, C., Hawken, P., Holling, C. S., McMichael, T., et al. (2000). Managing our environmental portfolio. *BioScience*, 50, 149–155.

Find this resource:

Costanza, R., Waigner, L., Folke, C., & Mäler, K.-G. (1993). Modeling complex ecological economic systems: Toward an evolutionary dynamic understanding of people and nature. *BioScience*, 43, 545–555.

Find this resource:

Crane, T. A. (2010). Of models and meanings: Cultural resilience in social–ecological systems. *Ecology and Society*, 15(4), 19.

Find this resource:

Crepin, A.-S., Biggs, R., Polasky, S., Troell, M., & de Zeeuw, A. (2012). Regime shifts and management. *Ecological Economics*, 84, 15–22.

Find this resource:

Cretney, R. (2014). Resilience for whom? Emerging critical geographies of socio-ecological resilience. *Geography Compass*, 8(9), 627–640.

Find this resource:

Crona, B., & Bodin, Ö. (2006). **What you know is who you know? Communication patterns among resource users as a prerequisite for co-management.** *Ecology and Society*, 11(2), 7.

Find this resource:

Crona, B., & Bodin, Ö. (2010). Power asymmetries in small-scale fisheries: A barrier to governance transformability? *Ecology and Society*, 15(4), 32.

Find this resource:

Crona, B. I., & Parker, J. N. (2012). Learning in support of governance: Theories, methods, & a framework to assess how bridging organizations contribute to adaptive resource governance. *Ecology and Society*, 17(1), 32.

Find this resource:

Crona, B. I., van Holt, T., Petersson, M., Daw, T. M., & Buchary, E. (2015). Using social–ecological syndromes to understand impacts of international seafood trade on small-scale fisheries. *Global Environmental Change*, 35, 162–175.

Find this resource:

Cumming, G. S. (2011). *Spatial resilience of social-ecological systems*. New York: Springer Verlag.

Find this resource:

Cumming, G. S., Buerkert, A., Hoffmann, E. M., Schlecht, E., von Cramon-Taubadel, S., & Tschardtke, T. (2014). Implications of agricultural transitions and urbanization for ecosystem services. *Nature*, *515*, 50–57.

Find this resource:

Cumming, G. S., & Collier, J. (2005). Change and identity in complex systems. *Ecology and Society*, *10*(1), 29.

Find this resource:

Cumming, G. S., Olsson, P., Chapin III, F. S., & Holling, C. S. (2013). Resilience, experimentation, & scale mismatches in social-ecological landscapes. *Landscape Ecology*, *28*, 1139–1150.

Find this resource:

Curtin, C. G., & Parker, J. P. (2014). Foundations of resilience thinking. *Conservation Biology*, *28*, 912–923.

Find this resource:

Cury, P. M., Boyd, I. L., Bonhommeau, S., Anker-Nilssen, T., Crawford, R. J. M., Furness, R. W., et al. (2011). Global seabird response to forage fish depletion: One-third for the birds. *Science*, *334*, 1703–1706.

Find this resource:

Daily, G. C., & Ehrlich, P. R. (1992). Population, sustainability, & Earth's carrying capacity. *BioScience*, *42*, 761–771.

Find this resource:

Dakos, V., Scheffer, M., van Nes, E. H., Brovkin, V., Petoukhov, V., & Held, H. (2008). Slowing down as an early warning signal for abrupt climate change. *Proceedings of the National Academy of Sciences, USA*, *105*, 14308–14312.

Find this resource:

Dasgupta, P., & Mäler, K.-G. (Eds.). (2004). *The economics of non-convex ecosystems*. Dordrecht, The Netherlands: Kluwer Academic.

Find this resource:

Davidson-Hunt, I. J., & Berkes, F. (2003). Nature and society through the lens of resilience: Toward a human-in-ecosystem perspective. In F. Berkes, J. Colding, & C. Folke (Eds.), *Navigating social-ecological systems: Building resilience for complexity and change* (pp. 53–82). Cambridge, U.K.: Cambridge University Press.

Find this resource:

Davies, M., Béné, C., Arnall, A., Tanner, T., Newsham, A., & Coirolo, C. (2013). Promoting resilient livelihoods through adaptive social protection: Lessons from 124 programmes in South Asia. *Development Policy Review*, *31*, 27–58.

Find this resource:

Daw, T., Coulthard, S., Cheung, W. W. L., Brown, K., Abunge, C., Galafassi, D., et al. (2015). Evaluating taboo trade-offs in ecosystems services and human well-being. *Proceedings of the National Academy of Sciences, USA*, *112*, 6949–6954.

Find this resource:

De Zeeuw, A. (2014). Regime shifts in resource management. *Annual Review of Resource Economics*, *6*, 85–104.

Find this resource:

Desjardins, E., Barker, G., Lindo, Z., Dieleman, C., & Dussault, A. C. (2015). Promoting resilience. *The Quarterly Review of Biology*, *90*, 147–165.

Find this resource:

Deutsch, L., Gräslund, S., Folke, C., Huitric, M., Kautsky, N., Troell, M., et al. (2007). Feeding aquaculture growth through globalization: Exploitation of marine ecosystems for fishmeal. *Global Environmental Change*, *17*, 238–249.

Find this resource:

Díaz, S., Quétier, F., Cáceres, D. M., Trainor, S. F., Pérez-Harguindeguy, N., Bret-Harte, M. S., et al. (2011). Linking functional diversity and social actor strategies in a framework for interdisciplinary analysis of nature's benefits to society. *Proceedings of the National Academy of Sciences*, *108*(2), 895–902.

Find this resource:

Dietz, T., Ostrom, E., & Stern, P. C. (2003). The struggle to govern the commons. *Science*, *302*, 1902–1912.

Find this resource:

Djalante, R., Holley, C., Thomalla, F., & Carnegie, M. (2013). Pathways for adaptive and integrated disaster resilience. *Natural Hazards*, *69*, 2105–2135.

Find this resource:

Duit, A., Galaz, V., Eckerberg, K., & Ebbesson, J. (2010). Governance, complexity, & resilience. *Global Environmental Change*, *20*, 363–368.

Find this resource:

Ebbesson, J. (2010). The rule of law in governance of complex socio-ecological changes. *Global Environmental Change*, *20*, 414–422.

Find this resource:

Ebbesson, J., & Hey, E. (2013). Introduction: Where in law is social-ecological resilience? *Ecology and Society*, *18*(3), 25.

Find this resource:

Ekstrom, J. A., & Young, O. R. (2009). Evaluating functional fit between a set of institutions and an ecosystem. *Ecology and Society*, *14*(2), 16.

Find this resource:

Elmqvist, T., Folke, C., Nyström, M., Peterson, G., Bengtsson, J., Walker, B., & Norberg, J. (2003). Response diversity and ecosystem resilience. *Frontiers in Ecology and the Environment*, *1*, 488–494.

Find this resource:

Elmqvist, T., Fragkias, M., Goodness, J., Güneralp, B., Marcotullio, P. J., McDonald, R. I., et al. (Eds.). (2013). *Urbanization, biodiversity and ecosystem services: Challenges and opportunities*. New York: Springer.

Find this resource:

Ellis, E. C. (2015). Ecology in an anthropogenic biosphere. *Ecological Monographs*, *85*, 287–331.

Find this resource:

Enfors, E. (2013). Social-ecological traps and transformations in dryland agro-ecosystems: Using water system innovations to change the trajectory of development. *Global Environmental Change*, 23, 51–60.

Find this resource:

Enfors, E. I., Gordon, L. J., Peterson, G. D., & Bossio, D. (2008). Making investments in dryland development work: Participatory scenario planning in the Makanya catchment, Tanzania. *Ecology and Society*, 13(2), 42.

Find this resource:

Engle, N. L. (2011). Adaptive capacity and its assessment. *Global Environmental Change*, 21, 647–656.

Find this resource:

Eriksson, H., Österblom, H., Crona, B., Troell, M., Andrew, N., Wilen, J., et al. (2015). Contagious exploitation of marine resources. *Frontiers in Ecology and the Environment*, 13, 435–440.

Find this resource:

Ernstson, H., Barthel, S., Andersson, E., & Borgström S. T. (2010). Scale-crossing brokers and network governance of urban ecosystem services: The case of Stockholm. *Ecology and Society*, 15(4), 28.

Find this resource:

Ernstson, H., Sörlin, S., & Elmqvist, T. (2008). Social movements and ecosystem services: The role of social network structure in protecting and managing urban green areas in Stockholm. *Ecology and Society*, 13(2), 39

Find this resource:

Fairhead, J., Leach, M., & Scoones, I. (2012). Green grabbing: A new appropriation of nature? *Journal of Peasant Studies*, 39, 237–261.

Find this resource:

Fazey, I., Fazey, J. A., Fischer, J., Sherren, K., Warren, J., Noss, R. F., et al. (2007). Adaptive capacity and learning to learn as leverage for social-ecological resilience. *Frontiers in Ecology and the Environment*, 5, 375–380.

Find this resource:

Feola, G. (2015). Societal transformation in response to global environmental change: A review of emerging concepts. *Ambio*, 44, 376–390.

Find this resource:

Ferguson, B. C., Brown, R. R., & Deletic, A. (2013). A diagnostic procedure for transformative change based on transitions, resilience, & institutional thinking. *Ecology and Society*, 18(4), 57.

Find this resource:

Fernández-Giménez, M. E. (2015). “A shepherd has to invent”: Poetic analysis of social-ecological change in the cultural landscape of the central Spanish Pyrenees. *Ecology and Society*, 20(4), 29.

Find this resource:

Fischer, J., Gardner, T. A., Bennett, E. B., Balvanera, P., Biggs, R., Carpenter, S. R., et al. (2015). Advancing sustainability through mainstreaming a social-ecological systems perspective. *Current Opinion in Environmental Sustainability*, 14, 144–149.

Find this resource:

Fischer-Kowalski, M., & Rotmans, J. (2009). Conceptualizing, observing, & influencing social–ecological transitions. *Ecology and Society*, *14*(2), 3.

Find this resource:

Folke, C. (1991). Socio-economic dependence on the life-supporting environment. In C. Folke & T. Kåberger (Eds.), *Linking the natural environment and the economy: Essays from the Eco-Eco Group* (pp. 77–94). Dordrecht, Netherlands: Kluwer Academic.

Find this resource:

Folke, C. (2006). Resilience: The emergence of a perspective for social-ecological systems analyses. *Global Environmental Change*, *16*, 253–267.

Find this resource:

Folke, C., Carpenter, S., Elmqvist, T., Gunderson, L., Holling, C. S., & Walker, B. (2002). Resilience and sustainable development: Building adaptive capacity in a world of transformations. *Ambio*, *31*, 437–440.

Find this resource:

Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Elmqvist, T., Gunderson, L., et al. (2004). Regime shifts, resilience and biodiversity in ecosystem management. *Annual Review of Ecology, Evolution and Systematics*, *35*, 557–581.

Find this resource:

Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chapin III, F. S., & Rockström, J. (2010). Resilience thinking: Integrating resilience, adaptability and transformability. *Ecology and Society*, *15*(4), 20.

Find this resource:

Folke, C., Chapin III, F. S., & Olsson, P. (2009). Transformations in ecosystem stewardship. In F. S. Chapin III, G. P. Kofinas, & C. Folke (Eds.), *Principles of ecosystem stewardship: Resilience-based natural resource management in a changing world* (pp. 103–125). New York: Springer Verlag.

Find this resource:

Folke, C., Colding, J., & Berkes, F. (2003). Synthesis: Building resilience and adaptive capacity in social-ecological systems. In F. Berkes, J. Colding, & C. Folke (Eds.), *Navigating social-ecological systems: building resilience for complexity and change* (pp. 352–387). Cambridge, U.K.: Cambridge University Press.

Find this resource:

Folke, C., Hahn, T., Olsson, P., & Norberg, J. (2005). Adaptive governance of social-ecological systems. *Annual Review of Environment and Resources*, *30*, 441–473.

Find this resource:

Folke, C., & Hall, L. (2014). *Reflections on people and the biosphere*. Stockholm: Langenskiölds.

Find this resource:

Folke, C., Holling, C. S., & Perrings, C. A. (1996). Biological diversity, ecosystems, and the human scale. *Ecological Applications*, *6*, 1018–1024.

Find this resource:

Folke, C., Jansson, Å., Larsson, J., & Costanza, R. (1997). Ecosystem appropriation by cities. *Ambio*, *26*, 167–172.

Find this resource:

Folke, C., Jansson, Å., Rockström, J., Olsson, P., Carpenter, S. R., Chapin, F. S., et al. (2011). Reconnecting to the biosphere. *Ambio*, 40, 719–738.

Find this resource:

Forbes, B. C. (2013). Cultural resilience of social-ecological systems in the Nenets and Yamal-Nenets Autonomous Okrugs, Russia: A focus on reindeer nomads of the tundra. *Ecology and Society*, 18(4), 36.

Find this resource:

Forbes, B. C., Stammer, F., Kumpula, T., Meschytyb, N., Pajunen, A., & Kaarlejarvi, E. (2009). High resilience in the Yamal-Nenets social-ecological system, West Siberian Arctic, Russia. *Proceedings of the National Academy of Sciences, USA*, 106, 22041–22048.

Find this resource:

Gadgil, M., Berkes, F., & Folke C. (1993). Indigenous knowledge for biodiversity conservation. *Ambio*, 22, 151–156.

Find this resource:

Galaz, V. (2005). Social-ecological resilience and social conflict: Institutions and strategic adaptation in Swedish water management. *Ambio*, 34, 567–572.

Find this resource:

Galaz, V. (2014). *Global environmental governance, technology and politics: The anthropocene gap*. Cheltenham, U.K.: Edward Elgar.

Find this resource:

Galaz, V., Biermann, F., Crona, B., Loorbach, D., Folke, C., Olsson, P., et al. (2012). Planetary boundaries: Exploring the challenges for global environmental governance. *Current Opinion in Environmental Sustainability*, 4, 80–87.

Find this resource:

Galaz, V., Crona, B., Österblom, H., Olsson, P., & Folke, C. (2012). Polycentric systems and interacting planetary boundaries: Emerging governance of climate change—ocean acidification—marine biodiversity. *Ecological Economics*, 81, 21–32.

Find this resource:

Galaz, V., Gars, J., Moberg, F., Nykvist, B., & Repinski, C. (2015). Why ecologists should care about financial markets. *Trends in Ecology and Evolution*, 30, 571–580.

Find this resource:

Galaz, V., Hahn, T., Olsson, P., Folke, C., & Svedin, U. (2008). The problem of fit among biophysical systems, environmental regimes and broader governance systems: Insights and emerging challenges. In O. Young, L. A. King, & H. Schroeder (Eds.), *Institutions and environmental change: Principal findings, applications, and research frontiers* (pp. 147–186). Cambridge, MA: MIT Press.

Find this resource:

Galaz, V., Moberg, F., Olsson, F., Olsson, E.-K., Paglia, E., & Parker, C. (2011). Institutional and political leadership dimensions of cascading ecological crises. *Public Administration*, 89, 361–380.

Find this resource:

Garmestani, A. S., Allen, C. R., & Benson, M. H. (2013). Can law foster social-ecological resilience? *Ecology and Society*, 18(2), 37.

Find this resource:

Geels, F. W., & Kemp, R. (2006). Transitions, transformations and reproduction: Dynamics in socio-technical systems. In M. D. McKelvey & M. Holmén (Eds.), *Flexibility and stability in the innovating economy* (pp. 227–257). Oxford: Oxford Scholarship Online Monographs.

Find this resource:

Geertz, C. (1973). *The interpretation of cultures: Selected essays*. New York: Basic Books.

Find this resource:

Gelcich, S., Edwards-Jones, G., Kaiser, M. J., & Castilla, J. C. (2006). Co-management policy can reduce resilience in traditionally managed marine ecosystems. *Ecosystems*, 9, 951–966.

Find this resource:

Gelcich, S., Hughes, T. P., Olsson, P., Folke, C., Defeo, O., Fernández, M., et al. (2010). Navigating transformations in governance of Chilean marine coastal resources. *Proceedings of the National Academy of Sciences, USA*, 107, 16794–16799.

Find this resource:

Goldstein, B. E. (Ed.). (2012). *Collaborative Resilience: Moving through Crisis to Opportunity*. MIT Press, Cambridge, MA, USA.

Find this resource:

Gómez-Baggethun, E., & Barton, D. N. (2013). Classifying and valuing ecosystem services for urban planning. *Ecological Economics*, 86, 235–245.

Find this resource:

Gómez-Baggethun, E., Corbera, E., & Reyes-García, V. (2013). Traditional ecological knowledge and global environmental change: Research findings and policy implications. *Ecology and Society*, 18(4), 72.

Find this resource:

Gordon L. J., Peterson, G. D., & Bennett E. M. (2008). Agricultural modifications of hydrological flows create ecological surprises. *Trends in Ecology and Evolution*, 23, 211–219.

Find this resource:

Goulden, M. C., Adger, W. N., Allison, E. H., & Conway, D. (2013). Limits to resilience from livelihood diversification and social capital in lake social-ecological systems. *Annals of the Association of American Geographers*, 103, 906–924.

Find this resource:

Graham, N. A. J., Bellwood, D. R., Cinner, J. E., Hughes, T. P., Norström, A. V., & Nyström, M. (2013). Managing resilience to reverse phase shifts in coral reefs. *Frontiers in Ecology and the Environment*, 11, 541–548.

Find this resource:

Green, O. O., Garmestani, A. S., Van Rijswijk, H. F. M. W., & Keessen, A. M. (2013). EU water governance: Striking the right balance between regulatory flexibility and enforcement? *Ecology and Society*, 18(2), 10.

Find this resource:

Grimm, N. B., Faeth, S. H., Golubiewski, N. E., Redman, C. L., Wu, J. G., Bai, X. M., et al. (2008). Global change and the ecology of cities. *Science*, 319, 756–760.

Find this resource:

Guerry, A. D., Polasky, S., Lubchenco, J., Chaplin-Kramer, R., Daily, G. C., Griffin, R., et al. (2015). Natural capital informing decisions: From promise to practice. *Proceedings of the National Academy of Sciences, USA*, 112, 7348–7355.

Find this resource:

Gunderson, L. H. (2000). Resilience in theory and practice. *Annual Review of Ecology and Systematics*, 31, 425–439.

Find this resource:

Gunderson, L. H. (2001). Managing surprising ecosystems in Southern Florida. *Ecological Economics*, 37, 371–378.

Find this resource:

Gunderson, L. H., Allen, C. R., & Holling, C. S. (Eds.). (2009). *Foundations of ecological resilience*. Washington, DC: Island Press.

Find this resource:

Gunderson, L. H., & Holling, C. S. (Eds.). (2002). *Panarchy: Understanding transformations in human and natural systems*. Washington, DC: Island Press.

Find this resource:

Gunderson, L. H., & Holling, C. S., & Light, S. S. (Eds.). (1995). *Barriers and bridges to the renewal of ecosystems and institutions*. New York: Columbia University Press.

Find this resource:

Gunderson, L. H., & Pritchard, L. (Eds.). (2002). *Resilience and the behavior of large-scale systems*. Washington, DC: Island Press.

Find this resource:

Hahn, T. (2011). Self-organized governance networks for ecosystem management: Who is accountable? *Ecology and Society*, 16(2), 18.

Find this resource:

Hahn, T., Olsson, P., Folke, C., & Johansson, K. (2006). Trust building, knowledge generation and organizational innovations: The role of a bridging organization for adaptive co-management of a wetland landscape around Kristianstad, Sweden. *Human Ecology*, 34, 573–592.

Find this resource:

Haider, J., Quinlan, A. E., & Peterson, G. D. (2012). Interacting traps: Resilience assessment of a pasture system in northern Afghanistan. *Planning Theory and Practice*, 13, 312–319.

Find this resource:

Hall, P. A., & Lamont, M. (Eds.). (2013). *Social resilience in the neoliberal era*. New York: Cambridge University Press.

Find this resource:

Hamel, G., & Välikangas, L. (2003). The quest for resilience. *Harvard Business Review*, 81(9), 52–63.

Find this resource:

Hammer, M., Jansson, A. M., & Jansson, B.-O. (1993). Diversity change and sustainability: Implications for fisheries. *Ambio*, 22, 97–105.

Find this resource:

Hanna, S., Folke, C., & Mäler, K.-G. (Eds.). (1996). *Rights to nature: Ecological, economic, cultural, & political principles of institutions for the environment*. Washington, DC: Island Press.

Find this resource:

Hansen, J., Sato, M., & Ruedy, R. (2012). Perception of climate change. *Proceedings of the National Academy of Sciences, USA*, 109, E2415–E2423.

Find this resource:

Harrison, P., Bobbins, K., Culwick, C., Humby, T.-L., La Mantia, C., Todes, A., et al. (2014). *Urban resilience thinking for municipalities*. Johannesburg, South Africa: University of the Witwatersrand, Gauteng City-Region Observatory,

Find this resource:

Hegmon, M., Peeples, M. A., Kinzig, A. P., Kulow, S., Meegan, C. M., & Nelson, M. (2008). Social transformation and its human costs in the prehispanic U.S. Southwest. *American Anthropologist*, 110, 313–324.

Find this resource:

Hentati-Sundberg, J., Hjelm, J., Boonstra, W. J., & Österblom, H. (2015). Management forcing increased specialization in a fishery system. *Ecosystems*, 18, 45–61.

Find this resource:

Hill, M., & Engle, N. L. (2013). Adaptive capacity: Tensions across scales. *Environmental Policy and Governance*, 23, 177–192.

Find this resource:

Hobman, E. V., & Walker, I. (2015). Stasis and change: Social psychological insights into social-ecological resilience. *Ecology and Society*, 20(1), 39.

Find this resource:

Holland, J. H. (1992). Complex adaptive systems. *Daedalus*, 121, 17–30.

Find this resource:

Holland, J. H. (1995). *Hidden order: How adaptation builds complexity*. Reading, MA: Addison-Wesley.

Find this resource:

Holling, C. S. (1973). Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics*, 4, 1–23.

Find this resource:

Holling, C. S. (Ed.). (1978). *Adaptive environmental assessment and management*. London: Wiley.

Find this resource:

Holling, C. S. (1986). The resilience of terrestrial ecosystems: Local surprise and global change. In W. C. Clark & R. E. Munn (Eds.), *Sustainable development of the biosphere* (pp. 292–317). London: Cambridge University Press.

Find this resource:

Holling, C. S. (1995). An ecologist's view of the Malthusian conflict. In K. Lindahl Kiessling & H. Landberg (Eds.), *Population, economic development and the environment* (pp. 79–103). Oxford: Oxford University Press.

Find this resource:

Holling, C. S., Berkes, F., & Folke, C. (1998). Science, sustainability, & resource management. In F. Berkes & C. Folke (Eds.), *Linking social and ecological systems* (pp. 342–362). Cambridge, U.K.: Cambridge University Press.

Find this resource:

Holling, C. S., & Chambers, A. D. (1973). Resource science: The nurture of an infant. *BioScience*, 23, 13–20.

Find this resource:

Holling, C. S., & Meffe, G. K. (1996). Command and control and the pathology of natural resource management. *Conservation Biology*, 10, 328–337.

Find this resource:

Holling, C. S., Schindler, D. W., Walker, B. H., & Roughgarden, J. (1995). Biodiversity in the functioning of ecosystems: An ecological synthesis. In C. A. Perrings, K.-G. Mäler, C. Folke, C. S. Holling, & B.-O. Jansson (Eds.), *Biodiversity loss: Ecological and Economic issues* (pp. 44–83). Cambridge, U.K.: Cambridge University Press.

Find this resource:

Homer-Dixon, T., Walker, B., Biggs, R., Crepin, A.-S., Folke, C., Folke, E. F., Lambin, et al. (2015). Synchronous failure: The emerging causal architecture of global crisis. *Ecology and Society*, 20(3), 6.

Find this resource:

Hornborg, A., McNeill, J. R., & Martinez-Alier, J. (Eds.). (2007). *Rethinking environmental history: World-system history and global environmental change*. Plymouth, U.K.: Altamira.

Find this resource:

Hughes, T. P., Baird, A. H., Bellwood, D. R., Card, M., Connolly, S. R., Folke, C., et al. (2003). Climate change, human impacts, and the resilience of coral reefs. *Science*, 301, 929–933.

Find this resource:

Hughes, T. P., Linares, C., Dakos, V., van de Leemput, I. A., & van Nes, E. H. (2013). Living dangerously on borrowed time during slow, unrecognized regime shifts. *Trends in Ecology and Evolution*, 28, 149–155.

Find this resource:

Hughes, T. P., Rodrigues, M. J., Bellwood, D. R., Ceccarelli, D., Hoegh-Guldberg, O., McCook, L. et al. (2007). Phase shifts, herbivory, and the resilience of coral reefs to climate change. *Current Biology*, 17, 360–365.

Find this resource:

Huitema, D., Mostert, E., Egas, W., Moellenkamp, S., Pahl-Wostl, C., & Yalcin, R. (2009). Adaptive water governance: Assessing the institutional prescriptions of adaptive (co-) management from a governance perspective and defining a research agenda. *Ecology and Society*, 14(1), 26.

Find this resource:

Janssen, M. A. (2002). *Complexity and ecosystem management*. Cheltenham, U.K.: Edward Elgar.

Find this resource:

Janssen, M. A. (2007). An update on the scholarly networks on resilience, vulnerability, and adaptation within the human dimensions of global environmental change. *Ecology and Society*, 12(2), 9.

Find this resource:

Janssen, M. A. & Scheffer, M. (2004). Overexploitation of renewable resources by ancient societies and the role of sunk-cost effects. *Ecology and Society*, 9(1), 6.

Find this resource:

Jansson, Å. (2013). Reaching for a sustainable, resilient urban future using the lens of ecosystem services. *Ecological Economics*, 86, 285–291.

Find this resource:

Jansson, Å., & Polasky, S. (2010). Quantifying biodiversity for building resilience for food security in urban landscapes: Getting down to business. *Ecology and Society*, 15(3), 20.

Find this resource:

Jouffray, J. B., Nyström, M., Norström, A. V., Williams, I. D., Wedding, L. M., JN Kittinger, et al. (2015). Identifying multiple coral reef regimes and their drivers across the Hawaiian archipelago. *Philosophical Transactions of the Royal Society B*, 370(1659), 20130268.

Find this resource:

Karpouzoglou, T., Dewulf, A., & Clark, J. (2016). Advancing adaptive governance of social-ecological systems through theoretical multiplicity. *Environmental Science & Policy*, 57, 1–9.

Find this resource:

Kates, R. W., & Clark, W. C. (1996). Environmental surprise: Expecting the unexpected? *Environment*, 3(2), 6–34.

Find this resource:

Kates, R. W., Travis, W. R., & Wilbanks, T. J. (2012). Transformational adaptation when incremental adaptations to climate change are insufficient. *Proceedings of the National Academy of Sciences*, 109, 7156–7161.

Find this resource:

Kelly, P. M., & Adger, W. N. (2000). Theory and practice in assessing vulnerability to climate change and facilitating adaptation. *Climatic Change*, 47, 325–352.

Find this resource:

Keys, P. W., van der Ent, R. J., Gordon, L. J., Hoff, H., Nikoli, R., & Savenije, H. H. G. (2012). Analyzing precipitation-sheds to understand the vulnerability of rainfall dependent regions. *Biogeosciences*, *9*, 733–746.

Find this resource:

Keys, P., Wang-Erlandsson, L., & Gordon, L. J. (2016). **Revealing invisible water: Moisture recycling as an ecosystem service.** *PLoS One*, *11*(3), e0151993.

Find this resource:

King, C. A. (2008). Community resilience and contemporary agri-ecological systems: Reconnecting people and food, and people with people. *Systems Research and Behavioral Science*, *25*, 111–124.

Find this resource:

Kupers, R. (Ed.). (2014). *Turbulence: A corporate perspective on collaborating for resilience*. Amsterdam: Amsterdam University Press.

Find this resource:

Lade, S. J., Niiranen, S., Hentati-Sundberg, J., Blenckner, T., Boonstra, W. J., Orach, K., et al. (2015). An empirical model of the Baltic Sea reveals the importance of social dynamics for ecological regime shifts. *Proceedings of the National Academy of Sciences, USA*, *112*, 11120–11125.

Find this resource:

Lade, S. J., Tavoni, A., Levin, S. A., & Schlüter, M. (2013). Regime shifts in a social-ecological system. *Theoretical Ecology*, *6*, 359–372.

Find this resource:

Laliberte, E., Wells, J. A., DeClerck, F., Metcalfe, D. J., Catterall, C. P., Queiroz, C., et al. (2010). Land-use intensification reduces functional redundancy and response diversity in plant communities. *Ecology Letters*, *13*, 76–86.

Find this resource:

Lambin, E. F., & Meyfroidt, P. (2011). Global land use change, economic globalization, & the looming land scarcity. *Proceedings of the National Academy of Sciences, USA*, *108*, 3465–3472.

Find this resource:

Lansing, J. S., & Kremer, J. N. (1993). Emerging properties of Balinese water temple networks: Coadaptation on a rugged fitness landscape. *American Anthropologist*, *95*, 97–114.

Find this resource:

Lazarus, E. D. (2014). Land grabbing as a driver of environmental change. *Area*, *46*, 74–82.

Find this resource:

Leach, M., Rockström, J., Raskin, P., Scoones, I., Stirling, A. C., Smith, A., et al. (2012). Transforming innovation for sustainability. *Ecology and Society*, *17*(2), 11.

Find this resource:

Leach, M., Scoones, I., & Stirling, A. (2010). *Dynamic sustainabilities: Technology, environment, social justice*. London: Routledge.

Find this resource:

Lebel, L., Anderies, J. M., Campbell, B., Folke, C., Hatfield-Dodds, S., Hughes, T. P., et al. (2006). Governance and the capacity to manage resilience in regional social-ecological systems. *Ecology and Society*, 11(1), 19.

Find this resource:

Leichenko, R. (2011). Climate change and urban resilience. *Current Opinion in Environmental Sustainability*, 3, 164–168.

Find this resource:

Lengnick L. (2015). *Resilient agriculture: Cultivating food systems for a changing planet*. Gabriola Island, BC, Canada: New Society.

Find this resource:

Lenton, T. M., Held, H., Kriegler, E., Hall, J. W., Lucht, W., Rahmstorf, S., et al. (2008). Tipping elements in the Earth's climate system. *Proceedings of the National Academy of Sciences, USA*, 105, 1786–1793.

Find this resource:

Leslie, P., & McCabe, J. T. (2013). Response diversity and resilience in social-ecological systems. *Current Anthropology*, 54, 114–143.

Find this resource:

Levin, S., Xepapadeas, T., Crepin, A.-S., Norberg, J., de Zeeuw, A., Folke, C., et al. (2013). Social-ecological systems as complex adaptive systems: Modeling and policy implications? *Environment and Development Economics*, 18, 111–132.

Find this resource:

Levin, S. A. (1998). Ecosystems and the biosphere as complex adaptive systems. *Ecosystems*, 1, 431–443.

Find this resource:

Levin, S. A., Barrett, S., Aniyar, S., Baumol, W., Bliss, C., Bolin, B., et al. (1998). Resilience in natural and socioeconomic systems. *Environment and Development Economics*, 3, 222–235.

Find this resource:

Liu, J., Dietz, T., Carpenter, S. R., Alberti, M., Folke, C., Moran, E., A., et al. (2007). Complexity of coupled human and natural systems. *Science*, 317, 1513–1516.

Find this resource:

Liu, J., Hull, V., Batistella, M., DeFries, R., Dietz, T., Fu, F., et al. (2013). Framing sustainability in a telecoupled world. *Ecology and Society*, 18(2), 26.

Find this resource:

Liu, W. (2014). The application of resilience assessment: Resilience of what, to what, with what? A case study based on Caledon, Ontario, Canada. *Ecology and Society*, 19(4), 21.

Find this resource:

Lockwood, M., Mitchell, M., Moore, S. A., & Clement, S. (2014). Biodiversity governance and social-ecological system dynamics: Transformation in the Australian Alps. *Ecology and Society*, 19(2), 13.

Find this resource:

Loorbach, D. (2007). *Transition management: New mode of governance for sustainable development*. Utrecht, Netherlands: International Books.

Find this resource:

Lorenz, D. F. (2013). The diversity of resilience: Contributions from a social science perspective. *Natural Hazards*, 67, 7–24.

Find this resource:

Lubchenco, J. (1998). Entering the century of the environment: A new social contract for science. *Science*, 279, 491–497.

Find this resource:

Ludwig, D., Jones, D. D., & Holling, C. S. (1978). Qualitative-analysis of insect outbreak systems: Spruce budworm and forests. *Journal of Animal Ecology*, 47, 315–332.

Find this resource:

Ludwig, D., Mangel, M., & Haddad, B. (2001). Ecology, conservation, & public policy. *Annual Review of Ecology and Systematics*, 32, 481–517.

Find this resource:

Lundberg, J., & Moberg, F. (2003). Mobile link organisms and ecosystem functioning: Implications for ecosystem resilience and management. *Ecosystems*, 6, 87–98.

Find this resource:

Luthe, T., & Wyss, R. (2015). Introducing adaptive waves as a concept to inform mental models of resilience. *Sustainability Science*, 10, 673–685.

Find this resource:

Lyon, C. (2014). Place systems and social resilience: A framework for understanding place in social adaptation, resilience, & transformation. *Society & Natural Resources*, 27, 1009–1023.

Find this resource:

Lyon, C., & Parkins, J. R. (2013). Toward a social theory of resilience: Social systems, cultural systems, and collective action in transitioning forest-based communities. *Rural Sociology*, 78, 528–549.

Find this resource:

Mäler, K.-G., & Li, C. Z. (2010). Measuring sustainability under regime shift uncertainty: A resilience pricing approach. *Environment and Development Economics*, 15, 707–719.

Find this resource:

Marcus, L., & Colding, J. (2014). Toward an integrated theory of spatial morphology and resilient urban systems. *Ecology and Society*, 19(4), 55.

Find this resource:

Margis, K. (2010). Community resilience: An indicator of social sustainability. *Society & Natural Resources*, 23, 401–416.

Find this resource:

Marshall, N. A., Park, S. E., Adger, W. N., Brown, K., & Howden, S. M. (2012). Transformational capacity and the influence of place and identity. *Environmental Research Letters*, 7, 034022.

Find this resource:

Marshall, N. A., & Stokes, C. J. (2014). Influencing adaptation processes on the Australian rangelands for social and ecological resilience. *Ecology and Society*, 19(2), 14.

Find this resource:

Marston, J. M. (2015). Modeling resilience and sustainability in ancient agricultural systems. *Journal of Ethnobiology*, 35, 585–605.

Find this resource:

Mathevet, R., Etienne, M., Lynam, T., & Calvet, C. (2011). Water management in the Camargue Biosphere Reserve: Insights from comparative mental models analysis. *Ecology and Society*, 16(1), 43.

Find this resource:

Mathevet, R., Thompson, J., Delanoë, O., Cheylan, M., Gil-Fourrier, C., Bonnin, M., et al. (2010). La solidarité écologique: Un nouveau concept pour une gestion intégrée des parcs nationaux et des territoires. *Natures Sciences Sociétés*, 4(18), 424–433.

Find this resource:

Mathevet, R., Thompson, J. D., Folke, C., & Chapin III, S. (2016). Protected areas and their surrounding territory: Socioecological systems in the context of ecological solidarity. *Ecological Applications*, 26, 5–16.

Find this resource:

Matson, P., Clark, W. C., & Andersson, K. (2016). *Pursuing sustainability: A Guide to the science and practice*. Princeton, NJ: Princeton University Press.

Find this resource:

McPhearson, T., Andersson, E., Elmqvist, T., & Frantzeskaki, N. (2015). Resilience of and through urban ecosystem services. *Ecosystem Services*, 12, 152–156.

Find this resource:

McSweeney, K., & Coomes, O. T. (2011). Climate-related disaster opens a window of opportunity for rural poor in northeastern Honduras. *Proceedings of the National Academy of Sciences, USA*, 108, 5203–5208.

Find this resource:

McWilliam, E. (2009). Teaching for creativity: From sage to guide to meddler. *Asia Pacific Journal of Education*, 29, 282–293.

Find this resource:

Meerow, S., & Newell, J. P. (2015). Resilience and complexity: A bibliometric review and prospects for industrial ecology. *Journal of Industrial Ecology*, 19, 236–251.

Find this resource:

Meijerink, S., & Huitema, D. (2010). Policy entrepreneurs and change strategies: Lessons from sixteen case studies of water transitions around the globe. *Ecology and Society*, 15(2), 21.

Find this resource:

Merrie, A., Dunn, D. C., Metian, M., Boustany, A. M., Takei, Y., Elferink, A. O., et al. (2014). An ocean of surprises: Trends in human use, unexpected dynamics, and governance challenges in areas beyond national jurisdiction. *Global Environmental Change*, 27, 19–31.

Find this resource:

Merrie, A., & Olsson, P. (2014). An innovation and agency perspective on the emergence and spread of Marine Spatial Planning. *Marine Policy*, 44, 366–374.

Find this resource:

Michon, G. (2011). Revisiting the resilience of chestnut forests in Corsica: From social-ecological systems theory to political ecology. *Ecology and Society*, 16(2), 5.

Find this resource:

Miller, F., Osbahr, H., Boyd, E., Thomalla, F., Bharwani, S., Ziervogel, G., et al. (2010). Resilience and vulnerability: Complementary or conflicting concepts? *Ecology and Society*, 15(3), 11.

Find this resource:

Mitchell, M., Griffith, R., Ryan, P., Walkerden, G., Walker, B., Brown, V. A., & Robinson, S. (2014). Applying resilience thinking to natural resource management through a “planning-by-doing” framework. *Society & Natural Resources*, 27, 299–314.

Find this resource:

Moberg, F., & Folke, C. (1999). Ecological services of coral reef ecosystems. *Ecological Economics*, 29, 215–233.

Find this resource:

Moore, M.-L., Tjornbo, O., Enfors, E., Knapp, C., Hodbod, J., Baggio, J. A., et al. (2014). Studying the complexity of change: Toward an analytical framework for understanding deliberate social-ecological transformations. *Ecology and Society*, 19(4), 54.

Find this resource:

Nayak, P. K., Oliveira, L. E., & Berkes, F. (2014). Resource degradation, marginalization, and poverty in small-scale fisheries: Threats to social-ecological resilience in India and Brazil. *Ecology and Society*, 19(2), 73.

Find this resource:

Nelson, D. R., Adger, W. N., & Brown, K. (2007). Adaptation to environmental change: Contributions of a resilience framework. *Annual Review of Environment and Resources*, 32, 395–419.

Find this resource:

Nemec, K. T., Chan, J., Hoffman, C., Spanbauer, T. L., Hamm, J. A., Allen, C. R., et al. (2013). Assessing resilience in stressed watersheds. *Ecology and Society*, 19(1), 34.

Find this resource:

Norberg, J., & Cumming, G. (Eds.). (2008). *Complexity theory for a sustainable future*. New York: Columbia University Press.

Find this resource:

Norgaard, R. B. (1989). The case for methodological pluralism. *Ecological Economics*, 1, 37–57.

Find this resource:

Norgaard, R. B. (1994). *Development betrayed: The end of progress and a coevolutionary revisioning of the future*. San Francisco: Routledge.

Find this resource:

Norris, F. H., Stevens, S. P., Pfefferbaum, B., & Wyche, K. F. (2008). Community resilience as a metaphor, theory, set of capacities, and strategy for disaster readiness. *American Journal of Community Psychology*, 41, 127–150.

Find this resource:

Norström, A., Nyström, M., Lokrantz, J., & Folke, C. (2009). Alternative states on coral reefs: Beyond coral-macroalgal phase shifts. *Marine Ecology Progress Series*, 376, 295–306.

Find this resource:

Nykvist, B., & von Heland, J. (2014). Social-ecological memory as a source of general and specified resilience. *Ecology and Society*, 19(2), 47.

Find this resource:

Nyström, M., & Folke, C. (2001). Spatial resilience of coral reefs. *Ecosystems*, 4, 406–417.

Find this resource:

Nyström, M., Folke, C., & Moberg, F. (2000). Coral reef disturbance and resilience in a human dominated environment. *Trends in Ecology and Evolution*, 15, 413–417.

Find this resource:

Nyström, M., Graham, N. A. J., Lokrantz, J., & Norström, A. V. (2008). Capturing the cornerstones of coral reef resilience: Linking theory to practice. *Coral Reefs*, 27, 795–809.

Find this resource:

Nyström, M., Norström, A. V., Bleckner, T., de la Torre Castro, M., Eklöf, J. S., Folke, C., et al. (2012). Confronting feedbacks of degraded marine ecosystems. *Ecosystems*, 15, 695–710.

Find this resource:

O'Brien, K. (2012). Global environmental change II: From adaptation to deliberate transformation. *Progress in Human Geography*, 36, 667–676.

Find this resource:

O'Brien, K., Hayward, B., & Berkes, F. (2009). Rethinking social contracts: Building resilience in a changing climate. *Ecology and Society*, 14(2), 12.

Find this resource:

O'Brien, K., Patwardhan, A., Pelling, M., Hallegatte, S., Maskrey, A., Oki, T., et al. (2012). Toward a sustainable and resilient future. In C. B. Field, V. Barros, T. F. Stocker, D. Qin, D. J. Dokken, K. L. Ebi, et al. (Eds.), *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of*

*Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC)* (pp. 437–486). Cambridge, U.K.: Cambridge University Press.

Find this resource:

O'Connell, D., Walker, B., Abel, N., & Grigg, N. (2015). *The resilience, adaptation and transformation assessment framework: From theory to application*. CSIRO, Dickson, ACT, Australia.

Find this resource:

Odum, E. P. (1989). *Ecology and our endangered life-support systems*. Sunderland, MA: Sinauer Associates.

Find this resource:

Olsson, P., & Folke, C. (2001). Local ecological knowledge and institutional dynamics for ecosystem management: A study of Lake Racken watershed, Sweden. *Ecosystems*, 4, 85–104.

Find this resource:

Olsson, P., Folke, C., & Hahn, T. (2004). Social-ecological transformation for ecosystem management: The development of adaptive co-management of a wetland landscape in southern Sweden. *Ecology and Society*, 9(4), 2.

Find this resource:

Olsson, P., Folke, C., & Hughes, T. P. (2008). Navigating the transition to ecosystem-based management of the Great Barrier Reef, Australia. *Proceedings of the National Academy of Sciences, USA*, 105, 9489–9494.

Find this resource:

Olsson, P., Folke, C., Galaz, V., Hahn, T., & Schultz, L. (2007). Enhancing the fit through adaptive co-management: Creating and maintaining bridging functions for matching scales in the Kristianstads Vattenrike Biosphere Reserve Sweden. *Ecology and Society*, 12(1), 28.

Find this resource:

Olsson, P., Galaz, V., & Boonstra, W. J. (2014). Sustainability transformations: A resilience perspective. *Ecology and Society*, 19(4), 1.

Find this resource:

Olsson, P., Gunderson, L. H., Carpenter, S. R., Ryan, P., Lebel, L., Folke, C., et al. (2006). Shooting the rapids: Navigating transitions to adaptive governance of social-ecological systems. *Ecology and Society*, 11(1), 18.

Find this resource:

Österblom, H., & Folke, C. (2013). Emergence of global adaptive governance for stewardship of regional marine resources. *Ecology and Society*, 18(2), 4.

Find this resource:

Österblom, H., & Folke, C. (2015). **Globalization, marine regime shifts, and the Soviet Union**. *Philosophical Transactions of the Royal Society London, Biological Sciences*, 370(1659), 20130278.

Find this resource:

Österblom, H., Jouffray, J.-B., Folke, C., Crona, B., Troell, M., Merrie, A., et al. (2015). **Transnational corporations as keystone actors in marine ecosystem**. *Plos One*, 10(5), e0127533.

Find this resource:

Österblom, H., Sissenwine, M., Symes, D., Kadin, M., Daw, T., & Folke, C. (2011). Incentives, social-ecological feedbacks, and European fisheries. *Marine Policy*, *35*, 568–574.

Find this resource:

Ostrom, E. (1990). *Governing the commons: The evolution of institutions for collective actions*. New York: Cambridge University Press.

Find this resource:

Ostrom, E. (1999). Review of linking social and ecological systems: Management practices and social mechanisms for building resilience. *Ecological Economics*, *28*, 151–153.

Find this resource:

Ostrom, E. (2005). *Understanding institutional diversity*. Princeton, NJ: Princeton University Press.

Find this resource:

Ostrom, E. (2007). A diagnostic approach for going beyond panaceas. *Proceedings of the National Academy of Sciences, USA*, *104*, 15181–15187.

Find this resource:

Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. *Science*, *325*, 419–422.

Find this resource:

Oteros-Rozas, E., Martín-López, B., Daw, T., Bohensky, E. L., Butler, J., Hill, R., et al. (2015). Participatory scenario planning in place-based social-ecological research: Insights and experiences from 23 case studies. *Ecology and Society*, *20*(4), 32.

Find this resource:

Pahl-Wostl, C. (2007). Transitions towards adaptive management of water facing climate and global change. *Water Resources Management*, *21*, 49–62.

Find this resource:

Pahl-Wostl, C., Craps, M., Dewulf, A., Mostert, E., Tabara, D., & Taillieu, T. (2007). Social learning and water resources management. *Ecology and Society*, *12*(2), 5.

Find this resource:

Pahl-Wostl, C., Lebel, L., Knieper, C., & Nikitina, E. (2012). From applying panaceas to mastering complexity: Toward adaptive water governance in river basins. *Environmental Science and Policy*, *23*, 24–34.

Find this resource:

Park, S. E., Marshall, N. A., Jakku, E., Dowd, A. M., Howden, S. M., Mendham, E., et al. (2012). Informing adaptation responses to climate change through theories of transformation. *Global Environmental Change*, *22*, 115–126.

Find this resource:

Parker, J. N., & Hackett, E. J. (2012). Hot spots and hot moments in scientific collaborations and social movements. *American Sociological Review*, *77*, 21–44.

Find this resource:

Pelling, M. (2011). *Adaptation to climate change: From resilience to transformation*. Oxford: Routledge.

Find this resource:

Perrings, C. A., Folke, C., & Mäler, K.-G. (1992). The ecology and economics of biodiversity loss: The research agenda. *Ambio*, *21*, 201–211.

Find this resource:

Perrings, C. A., Mäler, K.-G., Folke, C., Holling, C. S., & Jansson, B.-O. (Eds.). (1995). *Biodiversity loss: Ecological and economic issues*. Cambridge, U.K.: Cambridge University Press.

Find this resource:

Peterson, G. (2000). Political ecology and ecological resilience: An integration of human and ecological dynamics. *Ecological Economics*, *35*, 323–336.

Find this resource:

Peterson, G., Allen, C. R., & Holling, C. S. (1998). Ecological resilience, biodiversity, and scale. *Ecosystems*, *1*, 6–18.

Find this resource:

Peterson, G. D., Carpenter, S. R., & Brock, W. A. (2003). Uncertainty and management of multi-state ecosystems: An apparently rational route to collapse. *Ecology*, *84*, 1403–1411.

Find this resource:

Peterson, G. D., Cumming, G. S., & Carpenter, S. R. (2003). Scenario planning: A tool for conservation in an uncertain world. *Conservation Biology*, *17*, 358–366.

Find this resource:

Pickett, S. T. A., Cadenasso, M. L., & Grove, J. M. (2004). Resilient cities: Meaning, models, and metaphor for integrating the ecological, socio-economic, and planning realms. *Landscape and Urban Planning*, *69*, 369–384.

Find this resource:

Plieninger, T., & Bieling, C. (Eds.). (2012). *Resilience and the cultural landscape: Understanding and managing change in human-shaped environments*. Cambridge, U.K.: Cambridge University Press.

Find this resource:

Plieninger, T., Bieling, C., Ohnesorge, B., Schaich, H., Schleyer, C., & Wolff, F. (2013). Exploring futures of ecosystem services in cultural landscapes through participatory scenario development in the Swabian Alb, Germany. *Ecology and Society*, *18*(3), 39.

Find this resource:

Polasky, S., Carpenter, S. R., Folke, C., & Keeler, B. (2011). Decision-making under great uncertainty: Environmental management in an era of global change. *Trends in Ecology and Evolution*, *26*, 398–404.

Find this resource:

Polasky, S., de Zeeuw, A., & Wagener, F. (2011). Optimal management with potential regime shifts. *Journal of Environmental Economics and Management*, *62*, 229–240.

Find this resource:

Pu, B., & Qiu, Y. J. (2016). Emerging trends and new developments on urban resilience: A bibliometric perspective. *Current Urban Studies*, 4, 36–52.

Find this resource:

Quinlan, A. E., Berbes-Blazquez, M. L., Haider, J., & Peterson, G. D. (2015). Measuring and assessing resilience: Broadening understanding through multiple disciplinary perspectives. *Journal of Applied Ecology*, 53, 677–687.

Find this resource:

Rathwell, K. J., & Peterson, G. D. (2012). Connecting social networks with ecosystem services for watershed governance: A social-ecological network perspective highlights the critical role of bridging organizations. *Ecology and Society*, 17(2), 24.

Find this resource:

Raudsepp-Hearne, C., Peterson, G. D., & Bennett, E. M. (2010). Ecosystem service bundles for analyzing tradeoffs in diverse landscapes. *Proceedings of the National Academy of Sciences, USA*, 107, 5242–5247.

Find this resource:

Raudsepp-Hearne, C., Peterson, G. D., Tengö, M., Bennett, E. M., Holland, T., Benessaiah, K., et al. (2010). Untangling the environmentalist's paradox: Why is human well-being increasing as ecosystem services degrade? *BioScience*, 60, 576–589.

Find this resource:

Raymond, C. M., Fazey, I., Reed, M. S., Stringer, L. C., Robinson, G. M., & Evely, A. C. (2010). Integrating local and scientific knowledge for environmental management. *Journal of Environmental Management*, 91, 1766–1777.

Find this resource:

Redman, C. L. (2005). Resilience theory in archaeology. *American Anthropologist*, 107, 70–77.

Find this resource:

Redman, C. L., & Kinzig, A. P. (2003). Resilience of past landscapes: Resilience theory, society, and the longue durée. *Conservation Ecology*, 7(1), 14.

Find this resource:

Reid, W. V., Berkes, F., Milbanks, T., & Capistrano, D. (2006). *Bridging scales and knowledge systems: Concepts and applications in ecosystem assessments*. Washington, DC: Island Press.

Find this resource:

Resilience Alliance. (2010). **Assessing resilience in social-ecological systems: Workbook for practitioners**. Version 2.0.

Reyer, B., Biggs, R., Cumming, G. S., Elmqvist, T., & Hejnowicz, A. P. (2013). Getting the measure of ecosystem services: A social-ecological approach. *Frontiers in Ecology and the Environment*, 11, 268–273.

Find this resource:

Reyers, B., Nel, J. L., O'Farrell, P. J., Sitas, N., & Nel, D. C. (2015). Navigating complexity through knowledge coproduction: Mainstreaming ecosystem services into disaster risk reduction. *Proceedings of the National Academy of Sciences, USA*, 112, 7362–7368.

Find this resource:

Richter, A., & Dakos, V. (2015). Profit fluctuations signal eroding resilience of natural resources. *Ecological Economics*, *117*, 12–21.

Find this resource:

Rist, L., Felton, A., Nyström, M., Troell, M., Sponseller, R. A., Bengtsson, J., et al. (2014). Applying resilience thinking to production ecosystems. *Ecosphere*, *5*(6), 1–11.

Find this resource:

Robards, M., & Alessa, L. (2004). Timescapes of community resilience and vulnerability in the circumpolar north. *Human Dimensions and the Arctic System*, *57*, 415–427.

Find this resource:

Robards, M. D., Schoon, M. L., Meek, C. L., & Engle, N. L. (2011). The importance of social drivers in the resilient provision of ecosystem services. *Global Environmental Change*, *21*, 522–529.

Find this resource:

Rocha, J. C., Peterson, G. D., & Biggs, R. O. (2015). **Regime shifts in the Anthropocene: Drivers, risks, & resilience.** *PLoS ONE*, *10*(8), e0134639.

Find this resource:

Rockström, J., Falkenmark, M., Allan, T., Folke, C., Gordon, L., Jägerskog, A., et al. (2014). The unfolding water drama in the Anthropocene: Towards a resilience based perspective on water for sustainability. *Ecohydrology*, *7*, 1249–1261.

Find this resource:

Rockström, J., Falkenmark, M., Folke, C., Lannerstad, M., Barron, J., Enfors, E., et al. (2014). *Water resilience for human prosperity*. Cambridge, U.K.: Cambridge University Press.

Find this resource:

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin III, F. S., Lambin, E. F., et al. (2009). A safe operating space for humanity. *Nature*, *461*, 472–475.

Find this resource:

Rosen, F., & Olsson, P. (2013). Institutional entrepreneurs, global networks, and the emergence of international institutions for ecosystem-based management: The Coral Triangle Initiative. *Marine Policy*, *38*, 195–204.

Find this resource:

Rotarangi, S. J., & Stephenson, J. (2014). Resilience pivots: Stability and identity in a social-ecological-cultural system. *Ecology and Society*, *19*(1), 28.

Find this resource:

Rumbach, A., & Foley, D. (2014). Indigenous institutions and their role in disaster risk reduction and resilience: Evidence from the 2009 tsunami in American Samoa. *Ecology and Society*, *19*(1), 19.

Find this resource:

Scheffer, M. (2009). *Critical transitions in nature and society*. Princeton, NJ: Princeton University Press.

Find this resource:

Scheffer, M., Barrett, S., Carpenter, S. R., Folke, C., Greene, A. J., Holmgren, M., et al. (2015). Creating a safe operating space for the world's iconic ecosystems. *Science*, *347*, 1317–1319.

Find this resource:

Scheffer, M., & Carpenter, S. R. (2003). Catastrophic regime shifts in ecosystems: Linking theory to observation. *Trends in Ecology and Evolution*, *18*, 648–656.

Find this resource:

Scheffer, M., Carpenter, S. R., Foley, J., Folke, C., & Walker B. H. (2001). Catastrophic shifts in ecosystems. *Nature*, *413*, 591–596.

Find this resource:

Scheffer, M., Carpenter, S. R., Lenton, T. M., Bascompte, J., Brock, W., Dakos, V., et al. (2012). Anticipating critical transitions. *Science*, *338*, 344–348.

Find this resource:

Schill, C., Lindahl, T., & Crépin, A.-S. (2015). Collective action and the risk of ecosystem regime shifts: Insights from a laboratory experiment. *Ecology and Society*, *20*(1), 48.

Find this resource:

Schlüter, M., & Herrfahrdt-Pähle, E. (2011). Exploring resilience and transformability of a river basin in the face of socioeconomic and ecological crisis: an example from the Amudarya river basin, Central Asia. *Ecology and Society*, *16*(1), 32.

Find this resource:

Scholes, R. J., Reyers, B., Biggs, R., Spierenburg, M. J., & Duriappah, A. (2013). Multi-scale and cross-scale assessments of social-ecological systems and their ecosystem services. *Current Opinion in Environmental Sustainability*, *5*, 16–25.

Find this resource:

Schoon, M. L., & Cox, M. E. (2012). Understanding disturbances and responses in social-ecological systems. *Society & Natural Resources*, *25*, 141–155.

Find this resource:

Schultz, L., Folke, C., & Olsson, P. (2007). Enhancing ecosystem management through social-ecological inventories: Lessons from Kristianstads Vattenrike, Sweden. *Environmental Conservation*, *34*, 140–152.

Find this resource:

Schultz, L., Folke, C., Österblom, H., & Olsson, P. (2015). Adaptive governance, ecosystem management and natural capital. *Proceedings of the National Academy of Sciences, USA*, *112*, 7369–7374.

Find this resource:

Schultz, L., & Lundholm, C. (2010). Learning for resilience? Exploring learning opportunities in biosphere reserves. *Environmental Education Research*, *16*, 645–663.

Find this resource:

Scoones, I. (1999). New ecology and the social sciences: What prospects for a fruitful engagement? *Annual Review of Anthropology*, *28*, 479–507.

Find this resource:

Sellberg, M. M., Wilkinson, C., & Peterson G. D. (2015). Resilience assessment: A useful approach to navigate urban sustainability challenges. *Ecology and Society*, 20(1), 43.

Find this resource:

Sendzimir, J., Magnuszewski, P., Flachner, Z., Balogh, P., Molnar, G., Sarvari, A., et al. (2008). Assessing the resilience of a river management regime: Informal learning in a shadow network in the Tisza River Basin. *Ecology and Society*, 13(1), 11.

Find this resource:

Seto, K. C., Reenberg, A., Boone, C. G., Fragkias, M., Haase, D., Langanke, T., et al. (2012). Urban land teleconnections and sustainability. *Proceedings of the National Academy of Sciences, USA*, 109, 7687–7692.

Find this resource:

Simmie, J., & Martin R. (2010). The economic resilience of regions: Towards an evolutionary approach. *Cambridge Journal of Regions, Economy and Society*, 3, 27–43.

Find this resource:

Sjöstedt, M. (2015). Resilience revisited: Taking institutional theory seriously. *Ecology and Society*, 20(4), 23.

Find this resource:

Smit, B., & Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Global Environmental Change*, 16, 282–292.

Find this resource:

Smith, A., & Stirling, A. (2010). The politics of social-ecological resilience and sustainable socio-technical transitions. *Ecology and Society*, 15(1), 11.

Find this resource:

Steffen, W., Crutzen, J., & McNeill, J. R. (2007). The Anthropocene: Are humans now overwhelming the great forces of Nature? *Ambio*, 36, 614–621.

Find this resource:

Steffen, W., Persson, Å., Deutsch, L., Zalasiewicz, J., Williams, M., Richardson, K., et al. (2011). The Anthropocene: From global change to planetary stewardship. *Ambio*, 40, 739–761.

Find this resource:

Steffen, W., Richardson, K., Rockström, J., Cornell, S., Fetzer, I., Bennett, E., et al. (2015). Planetary Boundaries: Guiding human development on a changing planet. *Science*, 347, 736.

Find this resource:

Steneck, R. S., Hughes, T. P., Cinner, J. E., Adger, W. N., Arnold, S. N., Berkes, F., et al. (2011). Creation of a gilded trap by the high economic value of the Maine lobster fishery. *Conservation Biology*, 25, 904–912.

Find this resource:

Sterner, T., Troell, M., Vincent, J., Aniyar, S., Barrett, S., Brock, W., et al. (2006). Quick fixes for the environment: Part of the solution or part of the problem. *Environment*, 48(10), 20–27.

Find this resource:

Stone-Jovicich, S. (2015). Probing the interfaces between the social sciences and social-ecological resilience: Insights from integrative and hybrid perspectives in the social sciences. *Ecology and Society*, 20(2), 25.

Find this resource:

Sundstrom, S. M., Angeler, D. G., Garmestani, A. S., Garcia, J. H., & Allen, C. R. (2014). Transdisciplinary application of cross-scale resilience. *Sustainability*, 6, 6925–6948.

Find this resource:

Swart, R. J., Raskin, P., & Robinson, J. (2004). The problem of the future: Sustainability science, and scenario analysis. *Global Environmental Change*, 14, 137–146.

Find this resource:

Takeuchi, K., Elmqvist, T., Hatakeyama, M., Kauffman, J., Turner, N., & Zhou, D. (2014). Using sustainability science to analyse social–ecological restoration in NE Japan after the great earthquake and tsunami of 2011. *Sustainability Science*, 9, 513–526.

Find this resource:

Tengö, M., Brondizio, E. S., Elmqvist, T., Malmer, P., & Spierenburg, M. (2014). Connecting diverse knowledge systems for enhanced ecosystem governance: The multiple evidence base approach. *Ambio*, 43, 579–591.

Find this resource:

Thomas, D. S. G., & Twyman, C. (2005). Equity and justice in climate change adaptation amongst natural-resource-dependent societies. *Global Environmental Change*, 15, 115–124.

Find this resource:

Thyresson, M., Nyström, M., & Crona, B. (2011). Trading with resilience: Parrotfish trade and the exploitation of key-ecosystem processes in coral reefs. *Coastal Management*, 39, 396–411.

Find this resource:

Tidball, K. G. (2014). Seeing the forest for the trees: Hybridity and social-ecological symbols, rituals and resilience in postdisaster contexts. *Ecology and Society*, 19(4), 25.

Find this resource:

Tidball, K. G., Krasny, M. E., Svendsen, E., Campbell, L., & Helphand, K. (2010). Stewardship, learning, and memory in disaster resilience. *Environmental Education Research*, 16, 591–609.

Find this resource:

Tidball, K. G., & Stedman, R. (2012). Positive dependency and virtuous cycles: From resource dependence to resilience in urban social-ecological systems. *Ecological Economics*, 86, 292–299.

Find this resource:

Tompkins, E. (2005). Planning for climate change in small islands: Insights from national hurricane preparedness in the Cayman Islands. *Global Environmental Change*, 15, 139–149.

Find this resource:

Treml, E. A., Fidelman, P. I. J., Kininmonth, S., Ekstrom, J. A., & Bodin, Ö. (2015). Analyzing the (mis)fit between the institutional and ecological networks of the Indo-West Pacific *Global Environmental Change*, 31, 263–271.

Find this resource:

Troell, M., Naylor, R., Metian, M., Beveridge, M., Tyedmers, P., Folke, C., et al. (2014). Does aquaculture add resilience to the global food system? *Proceedings of the National Academy of Sciences, USA*, 111, 13257–13263.

Find this resource:

Trosper, R. L. (2005). Emergence unites ecology and society. *Ecology and Society*, 10(1), 14.

Find this resource:

Turner II, B. L. (2010). Vulnerability and resilience: Coalescing or paralleling approaches for sustainability science? *Global Environmental Change*, 20, 570–576.

Find this resource:

Turner II, B. L., Clark, W. C., Kates, R. W., Richards, J. F., Mathews, J. T., & Meyer W. B. (Eds.). (1990). *The Earth as Transformed by Human Action: Global and regional changes in the biosphere over the past 300 years*. Cambridge, U.K.: Cambridge University Press.

Find this resource:

Turner II, B. L., Kaspersen, R. E., Matson, P. A., McCarthy, J. J., Corell, R. W., Christensen, L., et al. (2003). A framework for vulnerability analysis in sustainability science. *Proceedings of the National Academy of Sciences, USA*, 100, 8074–8079.

Find this resource:

Turner, N. J., Davidson-Hunt, I. J., & O’Flaherty M. (2003). Living on the edge: Ecological and cultural edges as sources of diversity for social-ecological resilience. *Human Ecology*, 31, 439–461.

Find this resource:

Ullaha, I. I. T., Kuijtb, I., & Freeman, J. (2015). Toward a theory of punctuated subsistence change. *Proceedings of the National Academy of Sciences, USA*, 112, 9579–9584.

Find this resource:

van der Leeuw, S. E., & Aschan-Leygonie, C. (2005). A long-term perspective on resilience in socio-natural systems. In H. Liljeström & Svedin U. (Eds.). *Micro, meso, macro: Addressing complex systems couplings* (pp. 227–264). Singapore: World Scientific.

Find this resource:

von Heland, J., & Folke, C. (2014). A social contract with the ancestors: Culture and ecosystem services in southern Madagascar. *Global Environmental Change*, 24, 251–264.

Find this resource:

Voss, J., & Bornemann B. (2011). The politics of reflexive governance: Challenges for designing adaptive management and transition management. *Ecology and Society*, 16(2), 9.

Find this resource:

Walker, B., Holling, C. S., Carpenter, S. R., & Kinzig, A. (2004). Resilience, adaptability, and transformability in social-ecological systems. *Ecology and Society*, 9(2), 5.

Find this resource:

Walker, B., Kinzig, A., & Langridge, J. (1999). Plant attribute diversity, resilience, & ecosystem function: the nature and significance of dominant and minor species. *Ecosystems*, 2, 95–113.

Find this resource:

Walker, B., & Salt, D. (2006). *Resilience thinking*. Washington, DC: Island Press.

Find this resource:

Walker, B., & Salt, D. (2012). *Resilience practice: Building capacity to absorb disturbance and maintain function*. Washington, DC: Island Press.

Find this resource:

Walker, B. H. (1992). Biological diversity and ecological redundancy. *Conservation Biology*, 6, 18–23.

Find this resource:

Walker, B. H. (1993). Rangeland ecology: Understanding and managing change. *Ambio*, 22, 80–87.

Find this resource:

Walker, B. H., Abel, N., Anderies, J. M., & Ryan, P. (2009). Resilience, adaptability, and transformability in the Goulburn-Broken Catchment, Australia. *Ecology and Society*, 14(1), 12.

Find this resource:

Walker, B. H., Anderies, J. M., Kinzig, A. P., & Ryan, P. (Eds.). (2006). **Exploring resilience in social-ecological systems: Comparative studies and theory development**. *Ecology and Society*, 11(1), article 12.

Find this resource:

Walker, B. H., Barrett, S., Polasky, S., Galaz, V., Folke, C., Engström, et al. (2009). Looming global-scale failures and missing institutions. *Science*, 325, 1345–1346.

Find this resource:

Walker, B. H., Ludwig, D., Holling, C. S., & Peterman, R. M. (1981). Stability of semi-arid savanna grazing systems. *Journal of Ecology*, 69, 473–498.

Find this resource:

Walker, B. H., Pearson, L., Harris, M., Mäler, K.-G., Li, C. Z., Biggs, R., et al. (2010). Incorporating resilience in the assessment of inclusive wealth: An example from South East Australia. *Environmental and Resource Economics*, 45, 183–202.

Find this resource:

Walker, J., & Cooper, M. (2011). Genealogies of resilience: From systems ecology to the political economy of crisis adaptation. *Security Dialogue*, 42, 143–160.

Find this resource:

Walters, C. (1986). *Adaptive management of renewable resources*. New York: Macmillan.

Find this resource:

Walters, C. J., & Hilborn, R. (1978). Ecological optimization and adaptive management. *Annual Review of Ecology and Systematics*, 9, 157–188.

Find this resource:

Walters, C. J., & Holling C. S. (1990). Large-scale management experiments and learning by doing. *Ecology*, 71, 2060–2068.

Find this resource:

Weichselgartner, J., & Kelman, I. (2015). Geographies of resilience: Challenges and opportunities of a descriptive concept. *Progress in Human Geography*, 39, 249–267.

Find this resource:

West, S. P., & Schultz, L. (2015). Learning for resilience in the European Court of Human Rights: Adjudication as an adaptive governance practice. *Ecology and Society*, 20(1), 31.

Find this resource:

Westley, F., Olsson, P., Folke, C., Homer-Dixon, T., Vredenburg, H., Loorbach, D., et al. (2011). Tipping towards sustainability: Emerging pathways of transformation. *Ambio*, 40, 762–780.

Find this resource:

Westley, F., Tjömbo, O., Schultz, L., Olsson, P., Folke, C., Crona, B., et al. (2013). A theory of transformative agency in linked social-ecological systems. *Ecology and Society*, 18(3), 27.

Find this resource:

Westley, F., Zimmerman, B., & Quinn Patton, M. (2006). *Getting to maybe: How the world is changed*. Toronto: Random House.

Find this resource:

Wilkinson, C. (2012). Social-ecological resilience: Insights and issues for planning theory. *Planning Theory*, 11, 148–169.

Find this resource:

Wilkinson, C., Porter, L., & Colding, J. (2010). Metropolitan planning and resilience thinking: A practitioner's perspective. *Critical Planning Journal*, 17(summer), 25–44.

Find this resource:

Wilson, G. A. (2012). Community resilience, globalization, and transitional pathways of decision-making. *Geoforum*, 43, 1218–1231.

Find this resource:

Winfrey, R., & Kremen, C. (2009). Are ecosystem services stabilized by differences among species? A test using crop pollination. *Proceedings of the Royal Society B*, 276, 229–237.

Find this resource:

Wise, R. M., Fazey, I., Stafford Smith, M., Park, S. E., Eakin, H. C., Archer Van Garderen, E. R. M., & Campbell, B. (2014). Reconceptualising adaptation to climate change as part of pathways of change and response. *Global Environmental Change*, 28, 325–336.

Find this resource:

Xu, L., & Marinova, D. (2013). Resilience thinking: A bibliometric analysis of socio-ecological research. *Scientometrics*, *96*, 911–927.

Find this resource:

Young, O. R. (2010). Institutional dynamics: Resilience, vulnerability, and adaptation in environmental and resource regimes. *Global Environmental Change*, *20*, 378–385.

Find this resource:

Young, O. R. (2011). Effectiveness of international environmental regimes: Existing knowledge, cutting-edge themes, and research strategies. *Proceedings of the National Academy of Sciences, USA*, *108*, 19853–19860.

Find this resource:

Young, O. R., Berkhout, F., Gallopin, G. C., Janssen, M. A., Ostrom, E., & van der Leeuw, S. (2006). The globalization of socio-ecological systems: An agenda for scientific research. *Global Environmental Change*, *16*, 304–316.

Find this resource:

### **Carl Folke**

The Beijer Institute of Ecological Economics, Royal Swedish Academy of Sciences; Stockholm Resilience Centre, Stockholm University

PRINTED FROM the OXFORD RESEARCH ENCYCLOPEDIA, ENVIRONMENTAL SCIENCE (environmentalscience.oxfordre.com). (c) Oxford University. All rights reserved. Reproduction or distribution in any form is strictly prohibited. Please see applicable Privacy Policy and Legal Notice (for details see Privacy Policy).

date: 27 January 2017

