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Resilience and Sustainable Development:

Theory of resilience, systems thinking and adaptive governance

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Resilience and Sustainable Development: Theory of resilience, systems thinking and adaptive governance

by

[Umberto Pisano](#)

This ESDN Quarterly Report (QR) provides a condensed overview of the concept of resilience. Despite the complexity of the theory behind resilience, this QR tries to communicate the main notions behind this concept in a way that is understandable and not overly technical. The intention of this QR is to serve as a guide through the concept of resilience. The report does not aim at being exhaustive but intends to provide an overview on the links which are particularly relevant for sustainable development (SD) in general and SD governance in particular.

A multitude of diverse sources have been used, mainly from the academic literature. It has to be mentioned the significant and decisive role that the Resilience Alliance has in providing extensive knowledge: the website that they are running, is an exceptionally good source of information for those who are interested and want to deepen their knowledge of resilience. Additionally, among all the scientific publications cited throughout the report, a special mention goes to the book by Walker and Salt (2006) entitled “Resilience thinking: sustaining ecosystems and people in a changing world”, which is very much suggested as a practical source of information on resilience.

As a first chapter, an executive summary is provided with a short overview of the report with the essential notions that are depicted throughout the QR. The second chapter then introduces the concept of resilience and gives an extensive background on the notions behind it. It intends to provide guidance, especially to understand the linkages between the concept of resilience and sustainable development, and the importance of resilience and systems thinking for policy-makers and for those who work on SD governance. The third chapter summarizes the relationships among resilience, society, governance and policy. Therefore, the concept of ‘adaptive governance’ is advanced as a more appropriate way to deal with complex issues that arise in social-ecological systems. The fourth chapter presents three practical examples of resilience. The first one is more general and reviews the case of climate change adaptation responses in relation to resilience. The second and the third examples analyse experiences with translating resilience into practice in Sweden and Australia respectively. Finally, some conclusions are drawn at the end of the report, where we propose reflections to better understand resilience.

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1 Executive Summary

The term “resilience” originated in the 1970s in the field of ecology from the research of C.S. Holling, who defined **resilience** as “*a measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables*” (Holling, 1973, p. 14). In short, resilience is best defined as “**the ability of a system to absorb disturbances and still retain its basic function and structure**” (Walker and Salt, 2006, p.1) and as “the capacity to change in order to maintain the same identity” (Folke et al., 2010).

Drawing from Carpenter et al. (2001), resilience can be best described by three crucial characteristics: (1) the amount of disturbance a system can absorb and still remain within the same state or domain of attraction; (2) the degree to which the system is capable of self-organization; and (3) the ability to build and increase the capacity for learning and adaptation.

In the *need for persistence*, we can find a first connection with sustainable development. Sustainable development has the objective of creating and *maintaining* prosperous social, economic, and ecological systems (Folke et al. 2002, p.1). Humanity has a *need for persistence*. And since humanity depends on services of ecosystems for its wealth and security, humanity and ecosystems are deeply linked. As a result, humanity has the imperative of striving for resilient socio-ecological systems in light of sustainable development.

Resilience thinking is inevitably systems thinking at least as much as sustainable development is. In fact, “when considering systems of humans and nature (social-ecological systems) it is important to consider the system as a whole. The human domain and the biophysical domain are interdependent” (Walker and Salt, 2006, pp.38). In this framework where resilience is aligned with systems thinking, *three concepts are crucial* to grasp (Walker and Salt, 2006): (1) humans live and operate in social systems that are inextricably linked with the ecological systems in which they are embedded; (2) social-ecological systems are complex adaptive systems that do not change in a predictable, linear, incremental fashion; and (3) resilience thinking provides a framework for viewing a social-eco-logical system as one system operating over many linked scales of time and space. Its focus is on how the system changes and copes with disturbance.

To fully understand the resilience theory, the report focuses therefore on the explanation of a number of crucial concepts: **thresholds**, the **adaptive cycle**, **panarchy**, **resilience**, **adaptability**, and **transformability**.

As shown, humanity and ecosystems are deeply linked. This is also the fundamental reason why to adopt the resilience-thinking framework is a necessity for **governance**. The resilience perspective shifts policies from those that aspire to control change in systems assumed to be stable, to **managing the capacity of social-ecological systems to cope with, adapt to, and shape change** (Berkes et al., 2003, Smit and Wandel, 2006). It is argued that managing for resilience enhances the likelihood of sustaining desirable pathways for development, particularly in changing environments where the future is unpredictable and surprise is likely (Walker et al., 2004; Adger et al., 2005).

This exposes the strong need for SD governance to embrace resilience thinking. It is not only about being *trans-disciplinary* and avoiding partial and one-viewpoint solutions; what is needed to solve today's problems – and especially those linked to sustainable development – is a new approach that considers humans as a part of Earth's ecosystems, and one in which policies can more effectively *cope with, adapt to, and shape change*.

In this scenario, the concept and key characteristics of the so-called '**adaptive governance**' seem to be a practical mean for societies to deal with the complex issues that social-ecological systems are confronted with. Therefore, adaptive governance is best understood as an approach that unites those environmental and natural resource management approaches that share some or all of the following principles: **polycentric and multi-layered institutions, participation and collaboration, self-organization and networks**, and **learning and innovation** (Djalante, Holley and Thomalla, 2011). Additionally, four interactive crucial aspects for adaptive governance are suggested: (1) to build knowledge and understanding of resource and ecosystem dynamics; (2) to feed ecological knowledge into adaptive management practices; (3) to support flexible institutions and multilevel governance systems; and, (4) to deal with external perturbations, uncertainty, and surprise (Folke et al., 2005). Therefore, nine values toward a 'resilient world' are also suggested: diversity, ecological variability, modularity, acknowledging slow variables, tight feedbacks, social capital, innovation, overlap in governance, ecosystem services (Walker and Salt, 2006).

Finally, three examples analyse few practical instances in terms of resilience: (1) the approach taken by the so-called **climate change adaptation discourse**; (2) the **Kristianstad Water Vattenrike**, a wetland in southern Sweden that showed problems with loss of wet meadows, decline of water quality, and a disappearing wildlife habitat; and, 3) the **Goulburn-Broken Catchment** from the State of Victoria (Australia). Few lessons can be drawn from these three cases. From the first case, governance structures have direct implications for the level of flexibility in responding to future change as well as variation in local contexts. Sensitivity to feedbacks relates both to the timing as well as where these feedbacks occur. Therefore, learning is more likely if feedbacks occur soon relative to action, and if those most affected by feedbacks are those responsible for the action. Additionally, the way in which a problem is conceptually framed determines the way in which responses are identified and evaluated and therefore influences the range of response characteristics. Second, the example from Sweden revealed that (a) the imposition of a set of rules to protect an ecosystem from the outside will not ensure the natural qualities of a region will be preserved over time. One size never fits all, and an understanding of local history and culture needs to be integrated into the management if local values are to be looked after; (b) for an organization to meaningfully deal with the complexity at many scales, it needs to include representatives from each of these levels in the social network; (c) several organizations need to be prepared to contribute to a shared vision and build consensus and leadership represents a crucial component in building adaptability and transformability. Third, the Goulburn-Broken story demonstrates the critical importance of understanding the underlying variables that drive a social-ecological system, knowing where thresholds lie along these variables, and knowing how much disturbance it will take to push the system across these thresholds (Walker and Salt, 2006).

2 What is resilience?

“At the heart of resilience thinking is a very simple notion – things change – and to ignore or resist this change is to increase our vulnerability and forego emerging opportunities. In so doing we limit our options. Sometimes changes are slow (...); sometimes they are fast (...). Humans are usually good at noticing and responding to rapid change. Unfortunately, we are not so good at responding to things that change slowly. In part this is because we don’t notice them and in part it’s because often there seems little we do about them. (Walker and Salt, 2006, pp.9-10)

2.1 Clarifying the concepts: resilience, system thinking and SD

The term “resilience” originated in the 1970s in the field of ecology from the research of C.S. Holling, who defined **resilience** as *“a measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables”* (Holling, 1973, p. 14).

Whilst analysing the behaviour of ecological systems, Holling (1973) suggested that this behaviour could be best defined through two distinct properties: resilience and stability. **“Resilience** determines the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state variables, driving variables, and parameters, and still persist. In this definition resilience is the property of the system and persistence or probability of extinction is the result. **Stability**, on the other hand, is the ability of a system to return to an equilibrium state after a temporary disturbance. The more rapidly it returns, and with the least fluctuation, the more stable it is. In this definition stability is the property of the system and the degree of fluctuation around specific states the result” (p.17).

In short, resilience is best defined as **“the ability of a system to absorb disturbances and still retain its basic function and structure”** (Walker and Salt, 2006, p.1). In other words, resilience is “the capacity to change in order to maintain the same identity” (Folke et al., 2010). In addition, “the concept of resilience in relation to social–ecological systems incorporates the idea of adaptation, learning and self-organization in addition to the general ability to persist disturbance” (Folke, 2006).

In time, the notion of resilience has known different descriptions and definitions that would have underpinned different aspects. As from Folke (2006), the following box presents three different facets of the concept of resilience that are well explained, especially in terms of their characteristics, their focuses, and their context.

Box 2.1: Three facets of resilience

Resilience concepts	Characteristics	Focus on	Context
<i>Engineering resilience</i>	Return time, efficiency	Recovery, constancy	Vicinity of a stable equilibrium
<i>Ecological resilience</i>	Buffer capacity, withstand shock, maintain function	Persistence, robustness	Multiple equilibria, stability landscapes
<i>Social–ecological resilience</i>	Interplay disturbance and reorganization, sustaining and developing	Adaptive capacity transformability, learning, innovation	Integrated system feedback, cross-scale dynamic interactions

Source: Folke (2006)

In our discourse the third definition, the so-called social-ecological resilience, is probably the best suited for considering governance issues. The first one - *engineering resilience* - is in fact too narrow and “focuses on maintaining efficiency of function, constancy of the system, and a predictable world near a single steady state. [In few words, this is only] about resisting disturbance and change, to conserve what you have” (Folke, 2006). On the other hand, the second definition is very much linked to ecosystems, even though it was also used by Adger (2000), who defined social resilience in relation to social change as “the ability of human communities to withstand external shocks to their social infrastructure, such as environmental variability or social, economic and political upheaval”.

Therefore, a very useful way to conceptualise resilience is through the definition of **social-ecological resilience** that, drawing from Carpenter et al. (2001), can be best described by three crucial characteristics:

1. the amount of disturbance a system can absorb and still remain within the same state or domain of attraction;
2. the degree to which the system is capable of self-organization;
3. the ability to build and increase the capacity for learning and adaptation.

2.2 The linkages with sustainable development

In evolutionary terms, a “population responds to any environmental change by the initiation of a series of physiological, behavioural, ecological, and genetic changes that restore its ability to respond to subsequent unpredictable environmental changes” (Holling, 1973, p.18). In Holling’s terms, therefore, the viewpoint of resilience emphasizes “the need for persistence”. In this perspective, striving for a management approach based on resilience would emphasize “the need to keep options open, the need to view events in a regional rather than a local context, and the need to emphasize heterogeneity [therefore requiring] a qualitative capacity to devise systems that can absorb and accommodate future events in whatever unexpected form they may take” (Holling, 1973, p.21).

In this *need for persistence*, we can find a first connection with sustainable development. Sustainable development has the objective of creating and *maintaining* prosperous social, economic, and ecological systems (Folke et al. 2002, p.1). Humanity has a *need for persistence*. And since humanity depends on services of ecosystems for its wealth and security, humanity and ecosystems are deeply linked. As a result, humanity has the imperative of striving for resilient socio-ecological systems in light of sustainable development.

A focus on ecosystems is therefore essential to understand the concept of resilience. In respect to this issue, in Folke et al. (2002), two fundamental errors of policies and of environmental management practices have been argued that let us understand the reason why resilience is so important. First error: until now there has been “an implicit assumption that ecosystem responses to human use are linear, predictable and controllable” (Folke et al. 2002, p.1). On the other hand, a second error underpins the “assumption that human and natural systems can be treated independently” (ibid.). In reality, *natural and social systems “behave in nonlinear ways, exhibit marked thresholds in their dynamics, and (...) social-ecological systems act as strongly coupled, complex and evolving integrated systems”* (ibid.).

Resilience thinking is therefore systems thinking at least as much as sustainable development is. In fact, “when considering systems of humans and nature (social-ecological systems) it is important to consider the system as a whole. The human domain and the biophysical domain are interdependent” (Walker and Salt, 2006, pp.38).

2.2.1 What is key for sustainable development?

Many scientists believe that the adoption of “resilience thinking provides a **framework** for viewing a social-ecological system as one system operating over many linked scales of time and space [notwithstanding that] its focus is on how the system changes and copes with disturbance” (Walker and Salt, 2006, pp.38).

In this framework where resilience is aligned with systems thinking, *three concepts are crucial* to grasp; these concepts can be drawn from the work of Walker and Salt (2006):

- 1. Humans live and operate in social systems that are inextricably linked with the ecological systems** in which they are embedded. This means that changes in one domain of the system, social or ecological, inevitably have impacts on the other domain; and, therefore, it is not possible to meaningfully understand the dynamics of one of the domains in isolation from the other. In fact, we exist in linked social and ecological systems but this is not reflected in the manner in which we traditionally analyse and practice natural resource management. We have economists who model “the economy,” sociologists who explain how and why human communities behave as they do, and scientists who attempt to unravel the biophysical nature of ecosystems. They all generate powerful insights into how the world works; but these insights are partial. They are only on components of the system rather than the system as a whole. This understanding calls for inter-disciplinary approaches in policy and research, based on systems thinking;
- 2. Social-ecological systems are complex adaptive systems** that do not change in a predictable, linear, incremental fashion; they have the potential to exist in more than one kind of regime (sometimes referred to as “alternate stable states”) in which their function, structure, and feedbacks are different. Shocks and disturbances to these systems can drive them across a threshold into a different regime, frequently with unwelcome surprises;
- 3. Resilience thinking provides a framework for viewing a social-eco-logical system as one system operating over many linked scales of time and space. Its focus is on how the system changes and copes with disturbance.** *Resilience is the capacity of a system to absorb*

disturbance; to undergo change and still retain essentially the same function, structure and feedbacks. In other words, it's the capacity to undergo some change without crossing a threshold to a different system regime, which is a system with a different identity.

In sustainability terms, a “resilient social-ecological system in a ‘desirable’ state has a greater capacity to continue providing us with the goods and services that support our quality of life while being subjected to a variety of shocks” (Walker and Salt, 2006, p.32).

In this regard, the concept of resilience is inevitably normative (Duit et al., 2010), as is the concept of sustainable development. What is a good system or a bad system is something that societies need to decide upon. In fact, both bad and good resilient systems can persist.

2.3 A brief historical overview of the concept

Resilience was originally introduced by Holling (1973) as a concept to help understand the capacity of ecosystems with alternative attractors to persist in the original state subject to perturbations (Folke et al., 2010). As shown in Schoon (2005), the definition¹ of ‘resilience’ is based almost exclusively on the work of C.S. Holling. Nearly all of the literature refers in one manner or another to various works by C.S. Holling.

In 1986, Holling refined his definition and defined resilience as “**the ability of a system to maintain its structure and patterns of behavior in the face of disturbance**” (Holling, 1986: p. 296). Holling offers up a third definition in *Barriers and Bridges to the Renewal of Ecosystems and Institutions*, which builds on the first two, stating that resilience is **the buffer capacity or the ability of a system to absorb perturbations, or the magnitude of disturbance that can be absorbed before a system changes its structure by changing the variables and processes that control behavior** (Holling et al., 1995).

Stuart Pimm’s 1984 article on the stability of ecosystems offers the only other moderately cited definition without strong affiliation to the work of C.S. Holling. He defines resilience as the measure of the speed of a system’s return to equilibrium following a perturbation. Holling, himself, acknowledges this measure of stability as “engineering resilience” and contrasts that with his preferred definition of resilience as a measure of absorptive capacity, which he denotes as “ecological resilience”. Other definitions not explicitly citing Holling tend to come from members of the Resilience Alliance, a research network with which Holling has long been affiliated.

A few definitions offer particularly relevant extensions of resilience, linking it to the concept of adaptation. Walker et al., (1981; p. 495) note that “resilience is the ability to adapt to change by exploiting instabilities” and that it is *not* simply “the ability to absorb disturbance by returning to a steady state after being disturbed”. Adger (2003: p. 1) concisely states that resilience “is the ability to persist *and* the ability to adapt”.

In the following **box** we present the conception of the resilience theory as explained by Holling in an

¹ Adapted from: Schoon, M. 2005. A Short Historical Overview of the Concepts of Resilience, Vulnerability, and Adaptation. Workshop in Political Theory and Policy Analysis Indiana University Working Paper W05-4. Available at: http://www.indiana.edu/~iupolsci/gradcv/schoon/historical_critique.pdf

email, as reported in Folke (2006). This is especially fascinating for those who are interested in understanding how theories are discovered and developed and what is behind science and scientists' enthusiasm in discoveries.

Box 2.2: How resilience came into play

"The 1973 paper emerged from a series of earlier experimental studies and papers analyzing a particular process, predation. The goal was to see how far one could go by being precise, realistic, general and integrative. That did well, turning up a way to classify categories of predation into four types of functional and three types of numerical responses. The categories and resulting simplified models seemed to apply to every- thing from bacteria foraging for food to mammals hunting prey. But none of that was ecosystem research. It was all traditionally experimental and analytical, but at least it was synthetic.

But a bridge to ecosystems started once I shifted to combine the predation equations with others concerning other processes in order to make a population model. That is when, suddenly and unexpectedly, multi-stable states appeared. Non-linear forms of the functional responses (e.g. the Type 3 S-shaped response) and of reproduction responses (e.g. the Allee effect) interacted to create two stable equilibria with an enclosed stability domain around one of them. Once discovered it was obvious that conditions for multi-stable states were inevitable. And that, being inevitable, there were huge consequences for theory and practice. Single equilibria and global stability had made ecology focus on near equilibria behavior, fixed carrying capacity with a goal of minimizing variability. The multi-stable state reality opened an entirely different focus on behavior far from equilibrium and on stability boundaries. High variability became an attribute to maintain existence and learning. Surprise and inherent unpredictability was the inevitable consequence for ecological systems. Low- density data and understanding was more important than high-density. I used the word resilience to represent this latter kind of stability.

Hence, the useful measure of resilience was the size of stability domains, or, more meaningfully, the amount of disturbance a system can take before its controls shift to another set of variables and relationships that dominate another stability region. And the relevant focus is not on constancy but on variability. Not on statistically easy collection and analysis for data but statistically difficult and unfamiliar ones.

About that time, I was invited to write the 1973 review article for the Annual Review of Ecology and Systematics on predation. I therefore decided to turn it into a review of the two different ways of perceiving stability and in so doing highlight the significance for theory and for practice. That required finding rare field data in the literature that demonstrated flips from one state to another, as well as describing the known non-linearities in the processes that caused or inhibited the phenomenon. That was a big job and I recall days when I thought it was all bunk, and days when I believed it was all real. I finished the paper on a 'good' day, when all seemed pretty clear. By then I guess I was convinced. The causal, process evidence was excellent, though the field evidence was only suggestive.

Nevertheless the consequences for theory and management were enormous.

(...) Some of the key features of ecosystems popped out: e.g. there had to be at least three sets of variables, each operating at qualitatively different speeds. There was an essential interaction across scales in space and time covering at least three orders of magnitude. Non-linearities were essential.

Multi-stable states were inevitable.

Surprise was the consequence.

It was the place where the "Adaptive Cycle" was first described and presented."

Holling, C.S. 2003

Source: Folke (2006)

2.4 The theory behind resilience

A clever way to introduce the theory behind resilience is to report a few lines of a 2010 article by Folke et al. that perfectly and clearly explain the most important characteristics of the issue. In their words, "resilience thinking addresses the dynamics and development of complex social–ecological systems (SES). Three aspects are [therefore] central: **resilience**, **adaptability**, and **transformability**. These aspects interrelate across multiple scales:

- *Resilience* in this context is the capacity of a SES to continually change and adapt yet remain within critical thresholds;
- *Adaptability* is part of resilience. It represents the capacity to adjust responses to changing external drivers and internal processes, and thereby allow for development along the current trajectory (stability domain);
- *Transformability* is the capacity to cross thresholds into new development trajectories.

Transformational change at smaller scales enables resilience at larger scales. The capacity to transform at smaller scales draws on resilience from multiple scales, making use of crises as windows of opportunity for novelty and innovation, and recombining sources of experience and knowledge to navigate social–ecological transitions”.

It is also very interesting to note that resilience “is not only about being persistent or robust to disturbance. It is also about the opportunities that disturbance opens up in terms of recombination of evolved structures and processes, renewal of the system and emergence of new trajectories” (Folke, 2006).

Although all of these concepts are very complex, we will try to introduce them in a condensed manner in order to provide a comprehensive overview, and will try not to be overly specific and detailed. Naturally, we will also provide links and references for those who are interested in going deeper into the theory.

With respect to this last aspect, we highly recommend reading the book “*Resilience Thinking. Sustaining ecosystems and people in a changing world*” by Brian Walker and David Salt (2006).² The following website also seems to be very useful: <http://www.resalliance.org/>. It provides a multitude of information, references, and examples of resilience. Additionally, a good source of useful knowledge is the reference list provided at the end of this report.

To fully understand the resilience theory, we need to focus on three crucial concepts: **thresholds**, the **adaptive cycle**, and **panarchy**. Since the subject we are treating is complex, we also decided to provide a glossary of the most important terms utilised at the end of this chapter (see pages 19-20). These terms are therefore explained and defined with the intention to help the reader overcome some of the obstacles of this difficult matter.

2.4.1 Thresholds

In the New Oxford American Dictionary, a threshold is defined as *the magnitude or intensity that must be exceeded for a certain reaction, phenomenon, result, or condition to occur or be manifested*.

In our discourse, a threshold also needs to be defined as “a breakpoint between two regimes of a system” (Walker and Meyers, 2004, p.3). Therefore, a threshold is the level or amount of a controlling, often slowly changing variable, in which a change occurs in a critical feedback, causing the system to self-organize along a different trajectory, that is, towards a different attractor.

Though social-ecological systems are affected by many variables, they are usually driven by only a handful of key controlling (often slow-moving) variables. Along each of these key variables are thresholds; if the system moves beyond a threshold it behaves in a different way, often with

² The next section is based very much on chapter 3 and 4 of this book.

undesirable and unforeseen surprises. Once a threshold has been crossed it is usually difficult (in some cases impossible) to cross back. A system's resilience can be measured by its distance from these thresholds. The closer it is to a threshold, the less it takes to be pushed over.

Social-ecological systems can exist in more than one kind of stable state. If a system changes too much it crosses a threshold and begins behaving in a different way, with different feedbacks between its component parts and a different structure. It is said to have undergone a "regime shift".

Therefore, very much related with the notion of threshold is the concept of "regime shift". A **regime shift** involving alternate stable states occurs when a threshold level of a controlling variable in a system is passed, such that the nature and extent of feedbacks change, resulting in a change of direction (the trajectory) of the system itself. A shift occurs when internal processes of the system (i.e. rates of birth, mortality, growth, consumption, decomposition, leaching, etc.) have changed and the state of the system (defined by the amounts of the state variables) begins to change in a different direction, toward a different attractor. In some cases, crossing the threshold brings about a sudden, large, and dramatic change in the responding state variables. In other cases, the response in the state variables is more gradual but, nevertheless, once the threshold has been passed, the feedbacks have changed and the dynamics of the system shift from one basin of attraction to another (Walker and Meyers, 2004, p.3).

2.4.2 The Adaptive Cycle

The other central theme to a resilience approach is how social-ecological systems change over time, hence, systems dynamics.

Social-ecological systems are always changing. By studying ecosystems all around the world, researchers have learned that most systems of nature usually proceed through recurring cycles consisting of **four phases**:

- *rapid growth* (or *exploitation*, **r** phase),
- *conservation* (**K** phase),
- *release* (or *creative destruction*, **omega** phase), and
- *reorganization* (or *renewal*, **alpha** phase) – usually, but not always, in that sequence (Holling, 1986).

The manner in which the system behaves is different from one phase to the next, with changes in the strength of the system's internal connections, its flexibility, and its resilience.

This is known as the **adaptive cycle**, as it *describes how an ecosystem organizes itself and how it responds to a changing world*. These cycles operate over many different scales of time and space. The manner in which they are linked across scales is crucially important for the dynamics of the whole set.

Understanding the significance of a system's internal connections, its capacity to respond to disturbance, and how these aspects change from phase to phase contributes to resilience thinking. This understanding is also important for policy and for managing natural resources because it suggests there are times in the cycle when there is greater leverage to change things, and other

times when affecting change is really difficult (like when things are in gridlock). The kinds of policy and management interventions appropriate in one phase don't work in others.

The four phases of the adaptive cycle in more detail

1. The rapid growth or exploitation phase (or r phase)³

Early in the cycle, the system is engaged in a period of rapid growth as species or people (i.e. a new business venture) exploit new opportunities and available resources. These species or actors make use of available resources to exploit every possible ecological or social niche. The system's components are weakly interconnected and its internal state is weakly regulated. The most successful of such actors are able to prosper under high environmental variation, and tend to operate over short timeframes.

Box 2.3: Some r-phase examples

- In ecosystems, they are classically the weeds and early pioneers of the world (alder on newly exposed sites in northern forests, or dock and pigweed on cleared lands).
- In economic systems, they are the innovators and entrepreneurs who seize upon opportunity (think of the explosive growth of Google and other dot com companies). They are start-ups and producers of new products who capture shares in newly opened markets and initiate intense activity.
- At higher scales we can think of the emergence and rapid growth and expansion of new societies, and even nations.

Source: Walker and Salt (2006)

2. The conservation (K phase)⁴

The transition to the conservation phase proceeds incrementally. During this phase, energy gets stored and materials slowly accumulate. Connections between the actors increase, and some of the actors change, though by the end of the growth phase few, if any, new actors are able to establish. The competitive edge shifts from opportunists to specialists who reduce the impact of variability through their own mutually reinforcing relationships. These ones live longer and are more conservative and efficient in their use of resources. They operate across larger spatial scales and over longer time periods. They are strong competitors. As the system's components become more strongly interconnected, its internal state becomes more strongly regulated. Prospective new entrants or new ways of doing things are excluded while capital grows (though it becomes increasingly harder to mobilize). Efficiency increases and the future seems ever more certain and determined. The growth rate slows as connectedness increases, the system becomes more and more rigid, and resilience declines. The cost of efficiency is a loss in flexibility. Different ways of performing the same function (redundancy) are eliminated in favor of simply performing the function in the most efficient way. Increasing dependence on existing structures and processes renders the system increasingly vulnerable to disturbance. Such a system is increasingly stable—but over a decreasing range of conditions.

³ r is the maximum rate of growth in growth models.

⁴ K is the parameter for "carrying capacity" or maximum population size in growth models.

Box 2.4: Some K-phase examples

- In a growing business this often translates to a move toward more specialization and the greater efficiencies of large economies of scale: bigger machines, bigger outputs, smaller costs per unit, larger profits over longer timeframes (for example, a steelmaking business that grows from a local producer to a national and then a global company).
- In an ecosystem, the capital that accumulates is stored in resources such as biomass. Increasingly, more of it becomes bound up in unavailable forms, like the heartwood of trees and dead organic matter. An economic system's capital can take the form of built capital (machines, buildings) and human capital (managerial and marketing skills and accumulated knowledge).

Source: Walker and Salt (2006)

3. The Release or creative destruction (or Omega, Ω , phase)

The transition from the conservation phase to the release phase can happen in a heartbeat. The longer the conservation phase persists the smaller the shock required to end it. A disturbance that exceeds the system's resilience breaks apart its web of reinforcing interactions. The system comes undone. Resources that were tightly bound are now released as connections break and regulatory controls weaken. The loss of structure continues as linkages are broken, and natural, social, and economic capital leaks out the system. In each case, through the brief release phase, the dynamics are chaotic. But the destruction that ensues has a creative element. Tightly bound capital is released and becomes a source for reorganization and renewal.

Box 2.5: Some Ω -phase examples

- In ecosystems, agents such as fires, drought, insect pests, and disease cause the release of accumulations of biomass and nutrients.
- In the economy, a new technology or a market shock can derail an entrenched industry.

Source: Walker and Salt (2006)

4. The Re-organization or Renewal (or Alpha, α , phase)

In the chaotic release phase, uncertainty rules; all options are open. It leads quickly into a phase of reorganization and renewal. Novelty can thrive. Small, chance events have the opportunity to powerfully shape the future. Invention, experimentation, and reassortment are the order of the day. In systems terms, the release phase is chaotic – there is no stable equilibrium, no attractor, no basin of attraction. The reorganization phase begins to sort out the players and to constrain the dynamics. The end of the reorganization phase and the beginning of the new rapid growth phase is marked by the appearance of a new attractor, a new "identity." Early in renewal, the future is up for grabs. This phase of the cycle may lead to a simple repetition of the previous cycle, or the initiation of a novel pattern of accumulation, or it may precipitate a collapse into a degraded state (in social systems, a poverty trap).

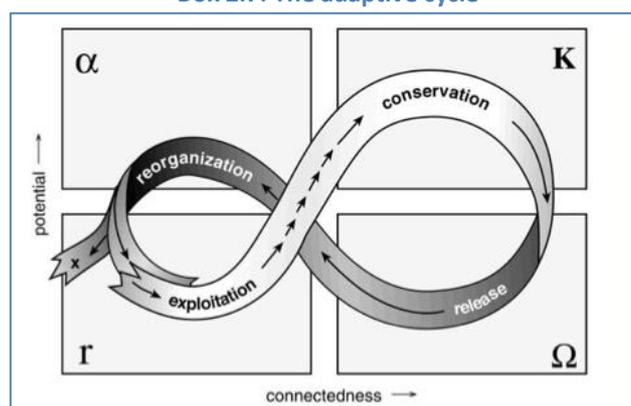
Box 2.6: Some α -phase examples

- In ecosystems, pioneer species may appear from elsewhere, or from previously suppressed vegetation; buried seeds germinate; new species (including nonnative plants and animals) can invade the system. Novel combinations of species can generate new possibilities that are tested later.
- In an economic or social system, new groups may appear and seize control of an organization. A handful of entrepreneurs released in an omega phase can meet and initiate a new renewal phase—turn a novel idea into a success (Nike shoes began in just this way). Skills, experience, and expertise lost by individual firms may coalesce around new opportunities. Novelty arises in the form of new inventions, creative ideas, and people.

Source: Walker and Salt (2006)

The adaptive cycle: feedbacks and loops

Usually, a system passes through an adaptive cycle by moving through the four phases in the order described here (i.e., rapid growth to conservation to release to renewal) (see the picture below). But this is not necessarily so. Systems cannot go directly from a release phase back to a conservation phase, but almost all other moves can occur.

Box 2.7: The adaptive cycle

Source: Walker and Salt (2006)

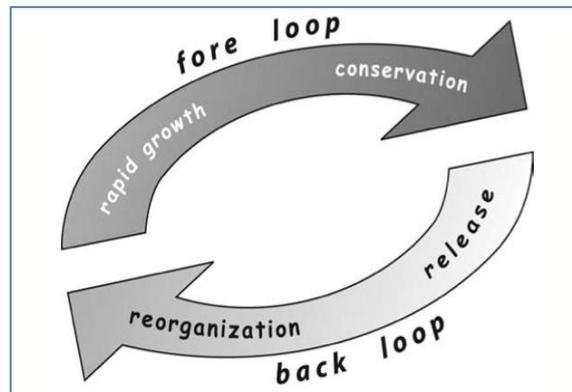
In box 2.7 above, it is possible to recognize not only the four phases just mentioned, but also another important feature of the adaptive cycle theory. Taken as a whole, the adaptive cycle has two opposing modes:

- a **fore loop** (sometimes called the *front loop* or *forward loop*), which is characterized by the accumulation of capital, by stability and conservation, a mode that is essential for system (and therefore human) well-being to increase;
- a **back loop** is characterized by uncertainty, novelty, and experimentation. The back loop is the time of greatest potential for the initiation of either destructive or creative change in the system. It is the time when human actions—intentional and thoughtful, or spontaneous and reckless—can have the biggest impact.

In the following Box 2.8, a simplified representation of the adaptive cycle shows these two phases in a more recognizable form. The rapid growth and conservation phases are referred to as the fore loop with relatively predictable dynamics, and in which there is a slow accumulation of capital and potential through stability and conservation. The release and reorganization phases are referred to

as the back loop, characterized by uncertainty, novelty, and experimentation, and during which there is a loss (leakage) of all forms of capital. The back loop is the time of greatest potential for the initiation of either destructive or creative change in the system.

Box 2.8: The simplified adaptive cycle



Source: Walker and Salt (2006)

It is important to reemphasize that the adaptive cycle is not an absolute; it is not a fixed cycle, and many variations exist in human and natural systems. A rapid growth phase usually proceeds into a conservation phase but it can also go directly into a release phase. A conservation phase usually moves at some point into a release phase but it can (through small perturbations) move back toward a growth phase. In the next box, a summary and some reflections on adaptive cycle are offered.

Box 2.9: Summary and some reflections on adaptive cycles

- Social-ecological systems are always changing, and many changes reflect a progression through linked adaptive cycles, on different scales of time and space, with each cycle consisting of four phases: **rapid growth** (r), **conservation** (K), **release** (omega) and **reorganization** (alpha).
- Most of the time, social-ecological systems are changing along the growth to conservation phases (**fore loop**) of the cycle in which growth and development are incremental, life is fairly predictable, and resources get locked up in doing things in an increasingly efficient manner. Optimization for immediate benefits can work in these phases (for a while).
- Inevitably, the conservation phase will end. The longer the conservation phase persists, the smaller the shock needed to end it and initiate a release phase in which linkages are broken and natural, social, and economic capital leaks out of the system. The system then reorganizes itself. In this **back loop** passage through release and reorganization, uncertainty and instability are high and optimization does not work.
- Because the **back loop** is a time of uncertainty and big change, in which the usual order undergoes significant and unpredictable rearrangement, it is feared and held off by those in power. However, no system can stay in, or be kept in, a late conservation phase indefinitely. Unless there is a deliberate effort to simplify the complexity, to release some of the potential and slide back toward the rapid growth phase, or engineer a very rapid, minimal cost conservation-to-reorganization transition, a significant back loop of one form or another is inevitable.
- A **back loop** is not all bad. It is a time of renewal and rejuvenation, a **period of new beginnings and new possibilities** – hence its description as a period of creative destruction. And those new beginnings can often grow to be ruling paradigms in the next front loop. They are critical times to achieve change and reform in a constantly moving social-ecological system.
- While the cycle just described is the most common pattern of system dynamics, other transitions between the four phases can, and do, occur.

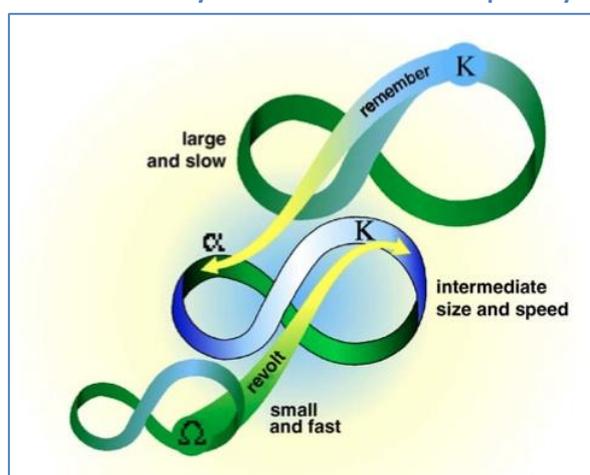
- Linkages across scales are very important for how the system as a whole operates.
- By understanding adaptive cycles, it is possible to: gain insight into how and why a system changes; develop a capacity to manage for a system's resilience; and, most importantly, learn where and when various kinds of management interventions will, and will not, work.

Source: Walker and Salt (2006)

2.4.3 Panarchy⁵

Any system is composed of a hierarchy of linked adaptive cycles operating at different scales (both in time and space). The structure and dynamics of the system at each scale is driven by a small set of key processes and, in turn, it is this linked set of hierarchies that govern the behavior of the whole system. This linked set of hierarchies is referred to as a “panarchy.” Very importantly, the processes that produce panarchy patterns are in turn reinforced by those patterns – that is, **the patterns and processes are self-organizing**. This is a key aspect of complex adaptive systems.

Box 2.10: Panarchy or linked multi-scale adaptive cycles



Source: Folke (2006)

As Box 2.10 shows, of particular interest are **linkages across scales**. They are a key aspect of the **multi-scale adaptive cycles** that make up a panarchy. What happens at one scale can influence or even drive what's happening at other scales. Ignoring the effects of one scale on another (**cross-scale effects**) is one of the most common reasons for failures in natural resource management systems. *The lesson is that you cannot understand or successfully manage a system by focusing on only one scale.*

The connections in the figure above labeled “**revolt**” and “**remember**” are examples of the interplay across scales that are of significance in the context of building resilience. An ecological example of revolt is a small ground fire that spreads to the crown of a tree, then to a patch in the forest, and then to a whole stand of trees. Each step in that cascade of events moves the disturbance to a larger and slower level. It is important to remember that a cross-scale connection is important in times of change, renewal, and re-organization. For example, following a fire in a forested ecosystem, the re-organization phase draws upon the seed bank, physical structures, and surviving species that had

⁵ See also Folke, 2006.

accumulated during the previous cycle of growth of the forest, plus those from the wider landscape. Thus, the ability for renewal and re-organization into a desired (from a human perspective) ecosystem state following disturbance will therefore strongly depend on the influences from states and dynamics at scales above and below and across time as well. Each level operates at its own pace, embedded in slower, larger levels, but invigorated by faster, smaller cycles.

Memory is the accumulated experience and history of the system, and it provides context and sources for renewal, recombination, innovation, novelty, and self-organization following disturbance.

The panarchy (as seen in the figure) is therefore both creative and conservative through the dynamic balance between rapid change and memory, and between disturbance and diversity and their cross-scale interplay. It sustains at the same time as it develops (Holling, 2001, cited in Folke 2006).

The last box of this chapter provides a useful glossary that is drawn using different sources as shown in the footnotes.

Box 2.11: A 'resilience' glossary^{6 7 8}

Adaptability (or adaptive capacity)	The capacity of actors in a system to influence resilience. Therefore, it is the adaptive capacity to manage resilience in relation to alternate regimes. It involves either or both of two abilities: <ol style="list-style-type: none"> 1. The ability to determine the trajectory of the system state - the position within its current basin of attraction; 2. The ability to alter the shape of the basins, that is move the positions of thresholds or make the system more or less resistant to perturbation.
Adaptive cycle	A heuristic model that portrays an endogenously driven four-phase cycle of social-ecological systems and other complex adaptive systems. <p>The common trajectory is from a <u>phase of rapid growth</u> (Exploitation or Growth, r) where resources are freely available and there is high resilience, through capital accumulation into a <u>gradually rigidifying phase</u> (Conservation, K) where most resources are locked up and there is little flexibility or novelty, and low resilience, thence via a <u>sudden collapse into a release phase</u> (Creative destruction or Release, Ω) of chaotic dynamics in which relationships and structures are undone, into a <u>phase of re-organization, innovation and restructuring</u> (Renewal, α) where novelty can prevail. The r-K dynamics reflect a more- or-less predictable, relatively slow "foreloop" and the Ω - α dynamics represent a chaotic, fast "backloop" that strongly influences the nature of the next foreloop. External or higher-scale influences can cause a move from any phase to any other phase.</p> <p>The growth and conservation phases together constitute a relatively long developmental period with fairly predictable, constrained dynamics; the release and reorganisation phases constitute a rapid, chaotic period during which capitals (natural, human, social, built and financial) tend to be lost and novelty can succeed.</p>
Attractor	An <i>attractor of a dynamical system</i> is a subset of the state space toward which orbits originating from typical initial conditions tend as time increases.
Basin of attraction	The set of initial conditions leading to long-time behaviour that approaches that

⁶ Folke, C., S.R. Carpenter, B. Walker, M. Scheffer, T. Chapin and J. Rockström. 2010. Resilience Thinking: Integrating Resilience, Adaptability and Transformability. *Ecology and Society* 15(4): 20.

⁷ [Resilience Alliance – Key concepts \(2012\)](#)

⁸ Walker, B., C.S. Holling, S.R. Carpenter and A. Kinzig. 2004. Resilience, Adaptability and Transformability in Social-ecological Systems. *Ecology and Society* 9(2): 5

	attractor.
Disturbance	In ecological terms, disturbance is a relatively discrete event in time coming from the outside, which disrupts ecosystems, communities, or populations, changes substrates and resource availability, and creates opportunities for new individuals or colonies to become established.
Latitude	The maximum amount the system can be changed before losing its ability to recover; basically the width of the basin of attraction.
Panarchy	The interacting set of hierarchically structured scales (of space, time, and social organization) and the interactive dynamics of a nested set of adaptive cycles. It is understood also in terms of how the attributes Precariousness, Resistance and Latitude are influenced by the states and dynamics of the (sub)-systems at scales above and below the scale of interest.
Precariousness	The current trajectory of the system, and how close it currently is to a limit or “threshold” which, if breached, makes recovery difficult or impossible.
Regime	It is a particular configuration of states and, more precisely, is understood as the set of system states within a stability landscape.
Resilience	It is the ability of a system to absorb disturbances and still retain its basic function and structure. It can be characterised also as: <ul style="list-style-type: none"> • General resilience as the resilience of any and all parts of a system to all kinds of shocks, including novel ones; • Specified resilience as the resilience “of what, to what” and, therefore, resilience of some particular part of a system, related to a particular control variable, to one or more identified kinds of shocks; • Engineering resilience is a measure of the rate at which a system approaches steady state following a perturbation, also measured as the inverse of return time
Resistance	The ease or difficulty of changing the system
Social-ecological system (SES)	Integrated system of ecosystems and human society with reciprocal feedback and interdependence. The concept emphasizes the humans-in-nature perspective.
Stability domain	A basin of attraction of a system, in which the dimensions are defined by the set of controlling variables that have threshold levels (equivalent to a system regime).
Stability landscape	The extent of the possible states of system space, defined by the set of control variables in which stability domains are embedded.
State space	Defined by the (state) variables that constitute the system. The state of the system at any time is defined by their current values.
Threshold (or critical transition)	A level or amount of a controlling, often slowly changing variable in which a change occurs in a critical feedback causing the system to self-organize along a different trajectory - that is, towards a different attractor.
Transformability	The capacity to create a fundamentally new system when ecological, economic, or social (including political) conditions make the existing system untenable. Transformability means defining and creating new stability landscapes by introducing new components and ways of making a living, thereby changing the state variables, and often the scale, that define the system.

3 Governance and resilience

“Social–ecological resilience is about people and nature as interdependent systems. This is true for local communities and their surrounding ecosystems, but the great acceleration of human activities on earth now also makes it an issue at global scales (Steffen et al. 2007), making it difficult and even irrational to continue to separate the ecological and social and to try to explain them independently, even for analytical purposes.” (Folke et al., 2010)

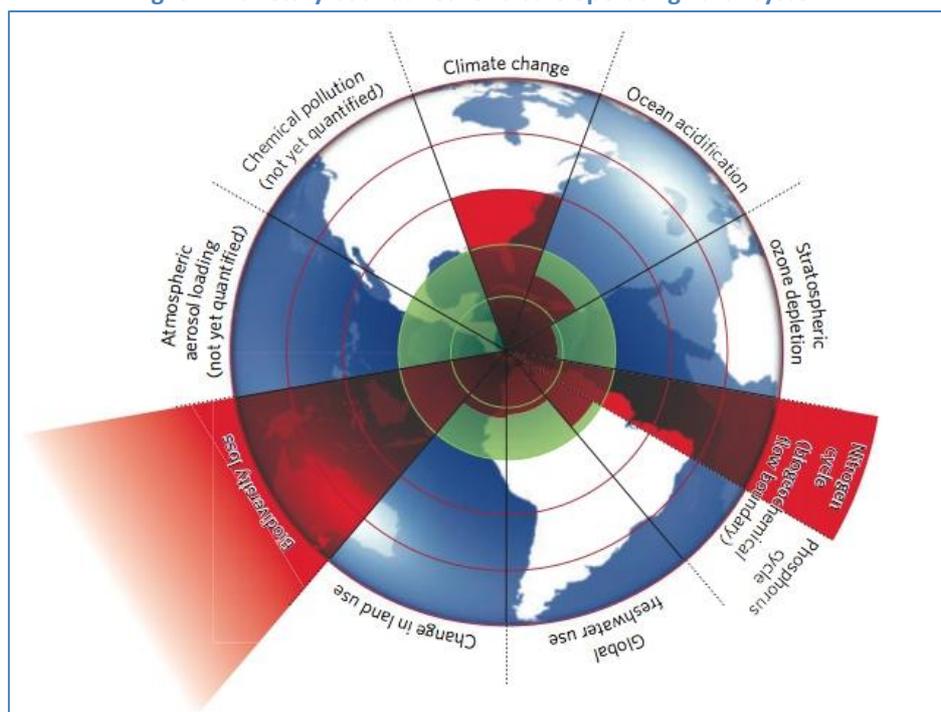
3.1 Society and ecosystems services

It is not as difficult as it may seem to justify why society should reflect on the fact that humanity is embedded in Earth’s ecosystems.

A very prominent article by Rockström et al. that appeared in Nature in September 2009 gave crucial new information; the article said: “although Earth has undergone many periods of significant environmental change, the planet’s environment has been unusually stable for the past 10,000 years. This period of stability — known to geologists as the Holocene — has seen human civilizations arise, develop and thrive. Such stability may now be under threat. Since the Industrial Revolution, a new era has arisen, the **Anthropocene**, in which human actions have become the main driver of global environmental change. This could see human activities push the Earth system outside the stable environmental state of the Holocene, with consequences that are detrimental or even catastrophic for large parts of the world”.

The scientists therefore developed a framework called of “**planetary boundaries**” that should be put under serious control and whose thresholds should not be crossed in order to avoid the disruption of the Earth stability domain. This framework is presented in the following figure that shows dramatically how some of these nine thresholds have been already exceeded, whilst some are in the momentum of being surpassed. The figure shows an inner green shading, representing the proposed safe operating space for nine planetary systems. The red wedges represent an estimate of the current position for each variable. The boundaries in three systems (rate of biodiversity loss, climate change, and human interference with the nitrogen cycle) have already been exceeded (Rockström et al., 2009).

Fig. 3.1 Planetary boundaries for a safe operating Earth system



Source: Rockström et al., 2009

Accordingly, Folke et al. in 2010 suggested that society should “seriously consider ways to foster resilience of smaller, more manageable Social-Ecological Systems that contribute to Earth System resilience, and to explore options for deliberate transformation of these Social-Ecological Systems that threaten Earth System resilience”.

In 2001, referring to the results of the Resilience Project⁹ he was participating in, Holling warned:

“the era of ecosystem management via incremental increases in efficiency is over. We are now in an era of transformation, in which ecosystem management must build and maintain ecological resilience as well as the social flexibility needed to cope, innovate, and adapt” (Holling, 2001)

These few examples taken from the academic literature, and from the recommendations of a large number of prominent scientists around the world, serve to emphasize the necessity for human society to heed these on-going recommendations and to take action.

This is especially true for those working in sustainable development (SD), in SD policy fields and governance, where trying to steer society is at the very heart of the work that they do.

“Humanity is a major force in global change and shapes ecosystem dynamics from local environments to the bio-sphere as a whole. At the same time human

⁹ The “Resilience Project” was a 5-year collaboration among an international group of ecologists, economists, social scientists, and mathematicians initiated in order to search for an integrative theory that had the degree of simplicity necessary for understanding but also the complexity required to develop policy for sustainability. The results of the Resilient project are summarized in the final report to the MacArthur Foundation found at <http://www.resalliance.org/reports>.

societies and globally interconnected economies rely on ecosystems services and support. It is now clear that patterns of production, consumption and wellbeing develop not only from economic and social relations within and between regions but also depend on the capacity of other regions' ecosystems to sustain them. Therefore, a major challenge is to develop governance systems that make it possible to relate to environmental assets in a fashion that secures their capacity to support societal development for a long time into the future. It will require adaptive forms of governance.

(Folke, 2006)

3.2 Why governance needs to adopt resilience thinking

An excerpt from Holling et al. (2002) will help us argue for the necessity of governance (especially governance for sustainable development) to consider and to adopt resilience thinking and its framework:

“The complex issues connected with the notion of sustainable development are not just ecological problems, nor economic or nor social. They are a combination of all three. Actions to integrate all three typically short-change one or more. Sustainable designs driven by conservation interests can ignore the needs for a kind of economic development that emphasize synergy, human ingenuity, enterprise and flexibility. Those driven by economic and industrial interests can act as if the uncertainty of nature can be replaced with human engineering and management controls, or ignored altogether. Those driven by social interests often presume that nature or a larger world presents no limits to the imagination and initiative of local groups. *Compromises among those viewpoints are arrived at through the political process.* However, mediation among stakeholders is irrelevant if based on ignorance of the integrated character of nature and people. The results may be satisfying to the participants, but ultimately reveal themselves as based upon unrealistic expectations about the behavior of natural systems. As investments fail, the policies of government, private foundations, international agencies and non-governmental organizations flop from emphasizing one kind of partial solution to another. Over the last three decades, such policies have flopped from large investment schemes, to narrow conservation ones to, at present, equally narrow community development ones. Each approach is built upon a particular world-view or theoretical abstraction, though many would deny anything but the most pragmatic and non-theoretical foundations. The conservationists depend on concepts rooted in ecology and evolution, the developers on variants of free market models, the community activists on precepts of community and social organization. All these views are correct. Correct in the sense of being partially tested and credible representations of one part of reality. The problem is that they are partial. They are *too simple and lack an integrative framework* that bridges disciplines and scales. (...) one way to *generate more robust foundations for sustainable decision making is to search for integrative theories* that combine disciplinary strengths while filling disciplinary gaps” (Holling et al., 2002, pp.3-4, emphases added).

In addition, Folke (2006) noted that old dominant perspectives have implicitly assumed a stable and infinitely resilient environment where resource flows could be controlled and nature would self-repair into equilibrium when human stressors were removed. Such static equilibrium-centered views provide little insight into the transient behaviour of systems that are not near equilibrium.

The resilience perspective shifts policies from those that aspire to control change in systems assumed to be stable, to **managing the capacity of social–ecological systems to cope with, adapt to, and shape change** (Berkes et al., 2003, Smit and Wandel, 2006). It is argued that managing for resilience enhances the likelihood of sustaining desirable pathways for development, particularly in changing environments where the future is unpredictable and surprise is likely (Walker et al., 2004; Adger et al., 2005).

This exposes the strong need for SD governance to embrace resilience thinking. It is not only about being *trans-disciplinary* and avoiding partial and one-viewpoint solutions; what is needed to solve today’s problems – and especially those linked to sustainable development - is a new approach that considers humans as a part of Earth’s ecosystems, and one in which policies can more effectively *cope with, adapt to, and shape change*.

In doing so, the so-called **Adaptive Governance approach** can credibly be of help.

3.3 Adaptive governance: concept and key characteristics

One of the most prominent institutes that studies resilience – the Stockholm Resilience Centre – considers **adaptive governance** as “an evolving research framework for analysing the social, institutional, economical and ecological foundations of multilevel governance modes that are successful in building resilience for the vast challenges posed by global change, and coupled complex adaptive Socio-Ecological Systems”.

In regard to this new field of governance, the Resilience Alliance put together a very interesting source of information that we recommend for further reading¹⁰. From this source – described as a *workbook for practitioners* - we suggest here a first comparison between what is considered as conventional governance and, on the other hand, what is referred to as adaptive governance, with the intention of introducing this significant concept.

Box 3.2: A first comparison between conventional governance and adaptive governance

Conventional governance	Adaptive governance
Stakeholder participation promoted for legitimacy and efficiency of management	Collective action and network-building promoted to strengthen capacity to deal with unexpected events
Social learning to create consensus around management initiatives	Social learning is institutionalized to understand system dynamics
Institutions designed to achieve fixed targets	Institutions designed for adaptation to environmental change

¹⁰ “Resilience Alliance. 2010. Assessing resilience in social-ecological systems. Workbook for practitioners. Version 2.0

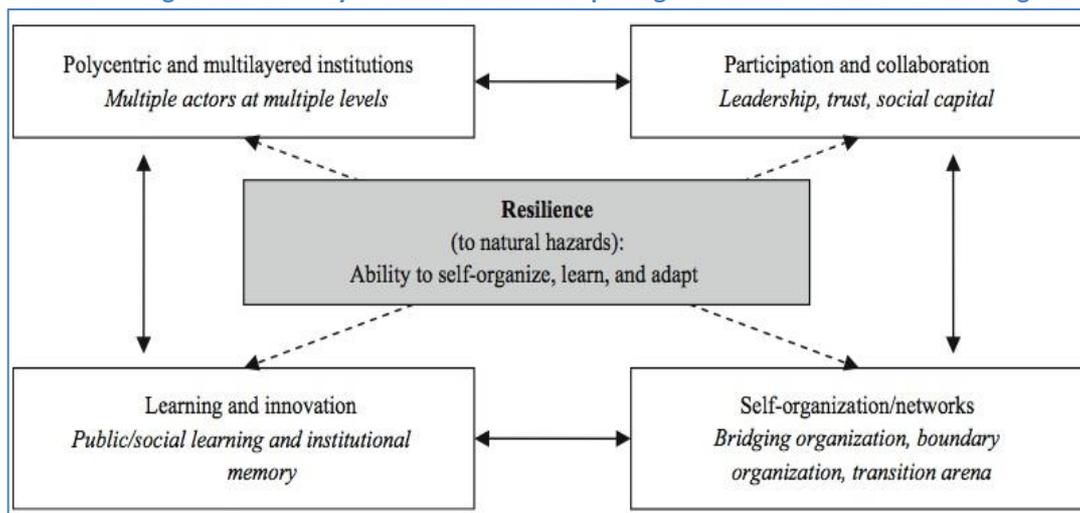
Evaluation is unsystematic and applied <i>ad hoc</i>	Policy viewed as hypotheses and management as experiments from which to learn
Strategies to deal with uncertainty are absent	Strategies to tackle uncertainty and complexity are a fundamental aim
Emphasis on solutions to achieve fixed quality and quantity targets	Emphasis on solutions to reduce vulnerability and strengthen capacity to respond and adapt
High reliance on models as a base in management plans	Models in collaborative processes important to understand behaviour of ecosystems and to identify critical thresholds
Institutional homogeneity promoted to secure administrative equality	Institutional diversity encouraged to promote innovation and reduce vulnerability
Multilevel governance encouraged for legitimacy and efficiency with regard to fixed targets	Multilevel governance promoted to secure local ecological knowledge, reduce vulnerability, and strengthen capacity

Source: Resilience Alliance (2010)

Therefore, adaptive governance is best understood as an approach that unites those environmental and natural resource management approaches that share some or all of the following principles: **polycentric and multi-layered institutions, participation and collaboration, self-organization and networks, and learning and innovation** (Djalante, Holley and Thomalla, 2011).

Reported from the same study, the next figure shows an illustrative representation of the links between the crucial characteristics of adaptive governance that will help in building and governing resilience. This figure successfully presents the conceptualization of the results of a number of studies conducted on governance modes and practices that build resilience and show high adaptive capacity. The authors explain that:

- The solid-line arrows in the figure show the main relationships among the characteristics. **Polycentric and multi-layered** institutions are the key steps in the directions for adaptive governance. These arrangements, along with **leadership, trust, and social capital**, can enhance the likelihood for **participation** and **collaboration**. **Self-organization** can be done formally or informally by whichever social arena formed and practiced in **different forms of networks**. These networks in turn help enhance **learning** and **innovation**, which can create enabling conditions for building resilience.
- The dashed lines represent indirect relationships. The existence of polycentric and multi-layered institutions helps to encourage self-organization and the formation of networks and vice versa, while participation and collaboration can further accelerate learning and innovation.

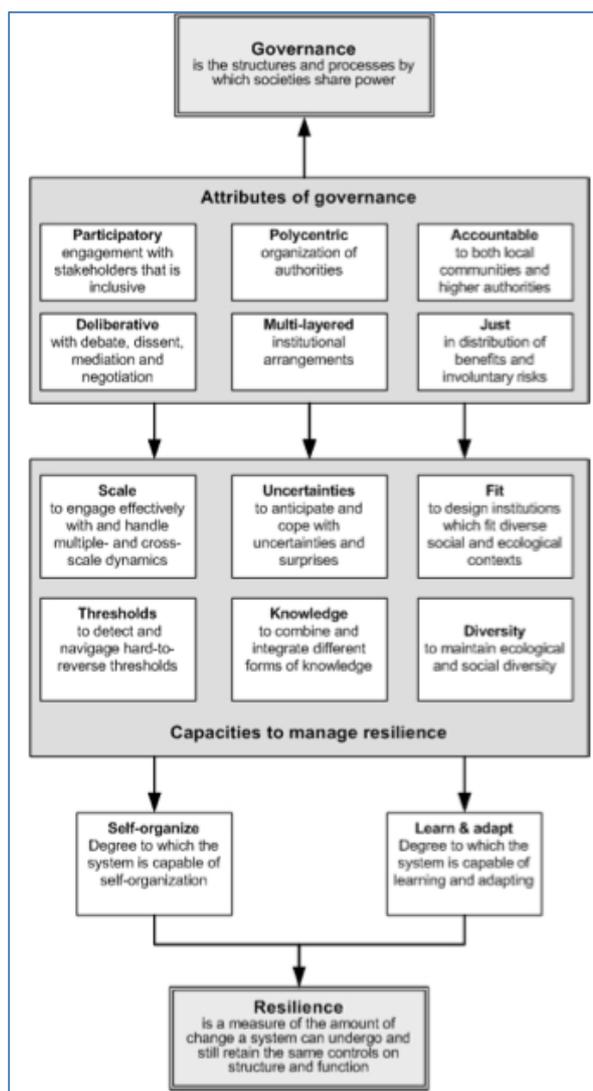
Box 3.3: Interlinkages between key characteristics of adaptive governance in relation to building resilience

Source: Djalante, Holley and Thomalla (2011)

The principles were developed taking into account a very interesting study that built on the following question: *How do certain attributes of governance function in society to enhance the capacity to manage resilience?* (Lebel et al., 2006).

The following figure is taken from this article, and shows very clearly how a number of governance attributes can relate well with the challenges that resilience poses and, therefore, with the capacity to manage resilience. Selected governance attributes that could viably help manage resilience include the following: **participatory, deliberative, polycentric, multi-layered, accountable, and just**. To add to those attributes, an attitude to foster **self-organisation** and the **capacity to learn and adapt** also seem to be very important.

Box 3.4: Governance attributes and resilience



Source: Lebel et al. (2006)

On the same line of thought is another prominent study that similarly studied the relationships between modes of governance and resilience in social-ecological systems. In their article, Folke et al. (2005) concluded by recommending *four interactive crucial aspects for adaptive governance*:

1. **Build knowledge and understanding of resource and ecosystem dynamics**; detecting and responding to environmental feedback in a fashion that contributes to resilience requires ecological knowledge and understanding of ecosystem processes and functions.
 - a. All sources of understanding need to be mobilized, and management of complex adaptive systems may benefit from the combination of different knowledge systems.
 - b. Social incentives for ecological knowledge generation need to be in place, as well as the capacity to monitor and translate signals (feedback) from ecosystem dynamics into knowledge that can be used in the social system.
2. **Feed ecological knowledge into adaptive management practices**; successful management is characterized by continuous testing, monitoring, and re-evaluation in order to enhance adaptive responses, acknowledging the inherent uncertainty in complex systems.

- a. It is increasingly proposed that knowledge generation of ecosystem dynamics should be explicitly integrated with adaptive management practices rather than striving for optimization based on past records. This aspect emphasizes a learning environment that requires leadership and changes of social norms within management organizations.
3. **Support flexible institutions and multilevel governance systems;** the adaptive governance framework is operationalized through adaptive co-management whereby the dynamic learning characteristic of adaptive management is combined with the multilevel linkage characteristic of co-management.
 - a. The sharing of management power and responsibility may involve multiple and often polycentric institutional and organizational linkages among user groups or communities, government agencies, and nongovernmental organizations, i.e., neither centralization nor decentralization, but cross-level inter- actions.
 - b. Adaptive co-management relies on the collaboration of a diverse set of stakeholders, operating at different levels through social networks. This aspect emphasizes the role of multilevel social networks to generate and transfer knowledge and develop social capital, as well as legal, political, and financial support to ecosystem management initiatives.
 4. **Deal with external perturbations, uncertainty, and surprise;** it is not sufficient for a well-functioning multilevel governance system to be in tune with the dynamics of the ecosystems under management. It also needs to develop capacity for dealing with changes in climate, disease outbreaks, hurricanes, global market demands, subsidies, and governmental policies.
 - a. The challenge for the social-ecological system is to accept uncertainty, be prepared for change and surprise, and enhance the adaptive capacity to deal with disturbance. Non-resilient social-ecological systems are vulnerable to external change, whereas a resilient system may even make use of disturbances as opportunities to transform into more desired states.

Box 3.5: Adaptive co-management: operationalizing adaptive governance for social-ecological systems

Since adaptive governance involves devolution of management rights and power sharing that promotes participation, a suggested way to operationalize is the so-called **adaptive co-management**. This is defined as a process by which institutional arrangements and ecological knowledge are tested and revised in a dynamic, ongoing, self-organized process of learning by doing (Folke et al., 2005). Adaptive co-management systems are flexible, community-based systems of resource management tailored to specific places and situations, and they are supported by and work with various organizations at different levels. The flexible structure allows for learning and ways of responding to and shaping change. Adaptive co-management combines the dynamic learning characteristic of adaptive management, along with the linkage characteristic of cooperative management and collaborative management. Co-management is concerned with the problem-solving process involved in sharing of management power across organizational levels. Adaptive co-management relies on the collaboration of a diverse set of stakeholders, operating at different levels, often through networks from local users to municipalities, to regional and national organizations, and also to international bodies.

Source: Folke et al. (2005)

3.4 Resilience thinking in practice¹¹

In general terms, resilience thinking is about appreciating the social-ecological system that one is interested in (and is a part of) as a complex adaptive system, and defining its key attributes (Walker and Salt, 2006). Therefore, most important questions to ask are systemic questions, for instance:

- What are the key slow **variables** that drive this system?
- As these variables changing, are there **thresholds** beyond which the system will behave in different ways?
- If so, where are these thresholds?
- Thresholds are defined by changes in **feedbacks**, so which important feedbacks in the system are likely to change under certain conditions?
- What **phase of the adaptive cycle** is the system moving through?
- What is happening in the adaptive cycles above and below the particular **scale** you are interested in?
- What are the **linkages between scales**?

In fact, when considering how to manage a system's resilience, the approach is to define the system in terms of thresholds and, therefore, to try to understand the key slow variables that are configuring the system (so-called **specified or targeted resilience**). However, resilience thinking needs to go beyond managing for specific variables and specific disturbances, and therefore it needs to properly consider maintaining the general capacities of a social-ecological system that allow it to absorb unforeseen disturbances (**general resilience**).

Three factors probably play an important role in maintaining general resilience: diversity, modularity, and the tightness of feedbacks:

- **Diversity** refers to variety in the number of species, people, and institutions that exist in a social-ecological system. It includes both functional and response diversity. The more variations available to respond to a shock, the greater the ability to absorb the shock. Diversity relates to flexibility and keeping your options open. A lack of diversity limits options and reduces your capacity to respond to disturbances. Increasing efficiency (optimization) inevitably leads to a reduction in diversity.
- **Modularity** relates to the manner in which the components that make up a system are linked. Highly connected systems (lots of links between all components) means shocks tend to travel rapidly through the whole system. Systems with subgroups of components that are strongly linked internally, but only loosely connected to each other, have a modular structure. A degree of modularity in the system allows individual modules to keep functioning when loosely linked modules fail, and the system as a whole has a chance to self-organize and therefore a greater capacity to absorb shocks.
- **Tightness of feedbacks** refers to how quickly and strongly the consequences of a change in one part of the system are felt and responded to in other parts. Institutions and social networks play key roles in determining tightness of feedbacks. Centralized governance and globalization can weaken feedbacks. As feedbacks lengthen, there is an increased chance of crossing a threshold without detecting it in a timely fashion.

Rather than focusing on the need to control natural variability and to maintain the system in some perceived optimal state, **a resilience approach to management and governance would instead focus on alternate system regimes and thresholds and the capacity to avoid or manage them.**

¹¹ This chapter is entirely based on the work of Walker and Salt (2006), which is a exceptional source of information

To operationalize this concept in practice, it is important for policy to reflect on few considerations that are summarised in the next box.

Box 3.6: Resilience thinking operationalised

1. You can't manage ecosystems or social systems in isolation. Their strong interactions mean that feedbacks between them must be taken into account.
2. When taking account of resilience it's important to know what phase of the adaptive cycle a system is in:
 - a. Is it nearing a change to a different phase?
 - b. What kinds of interventions are appropriate, or inappropriate, in the current phase?
3. An understanding of what is happening in the scales above and below the scale at which you are working is important:
 - a. What effect do these scales exert over the scale in which you are interested?
4. It's also important to identify the key (slow) controlling variables that may (or do) have threshold effects. Look for, and understand the drivers of, slowly changing variables (in the ecosystem and in the social system).
5. Identify any possible alternate regimes for the system, based on the controlling (slow) variables. Crossing in to an alternate regime will usually mean that the supply of goods and services from the system will alter.
6. Be aware that simplifying the system for increased efficiency reduces the system's diversity of possible responses to disturbance, and the system becomes more vulnerable to stresses and shocks.
7. Identify the key points for intervention that can avoid undesirable alternate regimes. This amounts to either changing the positions of thresholds (by identifying and managing the system attributes that determine them) or changing the trajectory of the system.
8. When help for communities/industries in trouble is warranted, devise subsidies for change, rather than subsidies not to change.
9. Invest in building adaptability (social capacity – *trust, leadership, networks*) and promote experimentation and learning.
10. Design or modify existing governance structures so that key intervention points can be addressed at the appropriate scales and times.
11. Acknowledge that there is a cost to maintaining resilience. It comes down to a trade-off between foregone extra profits in the short term, and long-term persistence and reduced costs from crisis management.
12. When the system has already moved into an undesirable regime (where the endpoint, or equilibrium, is unacceptable, and efforts are being made to keep away from it) there may come a time when adaptation is no longer socially or economically feasible. When transformation is the only option, the sooner it is recognized, accepted, and acted on, the lower the transaction costs and the higher the likelihood of success.

Source: Walker and Salt (2006)

3.4.1 What a resilient world would value

From the previous considerations, Walker and Salt (2006) interestingly suggest 9 points that would put the world in a “resilience” perspective. These points seem to be very motivating and appear to be especially attractive for spurring discussion. We report them here, as we believe that governance for SD particularly needs to take these issues in account:

1. Diversity

A resilient world would promote and sustain diversity in all forms (biological, landscape, social, and economic).

Diversity is a major source of future options and a system's capacity to respond to change and disturbance in different ways (recall response diversity, in particular). Resilient social-ecological systems would celebrate and encourage diversity – offsetting and complementing the existing trend toward homogenizing the world. It would encourage forms of multiple land and other resource use.

2. Ecological Variability

A resilient world would embrace and work with ecological variability (rather than attempting to control and reduce it).

Many of the biggest environmental problems we now face are a result of past efforts to dampen and control ecological variability (i.e. controlling flood levels and preventing species population “outbreaks”). Resilience is only maintained by probing its boundaries. A forest that is never allowed to burn soon loses its fire-resistant species, and becomes very vulnerable to a fire.

3. Modularity

A resilient world would consist of modular components.

In resilient systems everything is not necessarily connected to everything else. Over-connected systems are susceptible to shocks, which are rapidly transmitted through the system. A resilient system opposes such a trend; it would maintain or create a degree of modularity.

4. Acknowledging Slow Variables

A resilient world would have a policy focus on “slow,” controlling variables associated with thresholds.

By focusing on the key slow variables that configure a social-ecological system, and the thresholds that lie along them, we have a greater capacity to manage the resilience of a system. In doing so, it's possible to increase the space (size) of the desirable regime so that the system can absorb more disturbances that might be created by our actions, and thus avoid a shift into an undesirable regime. (Alternatively, if we are already in an undesirable regime, it enhances our ability to shift out of it.)

5. Tight Feedbacks

A resilient world would possess tight feedbacks (but not too tight).

A resilient social-ecological system would strive to maintain, or tighten, the strength of feedbacks. They allow us to detect thresholds before we cross them. Globalization is leading to delayed feedbacks that were once tighter; the people of the developed world receive weak feedback signals about the consequences of their consumption of developing world products. Feedbacks are loosening at all scales.

6. Social Capital

A resilient world would promote trust, well-developed social networks, and leadership (adaptability).

Resilience in social-ecological systems is very strongly connected to the capacity of the people in that system to respond, together and effectively, to change any disturbance. Trust, strong networks, and leadership are all important factors in making sure this can happen. So, too, is the existence of an institution that has strong penalties for cheaters (Ostrom, 1999). Individually these attributes contribute to what is generally termed “social capital,” but they need to act in concert to effect adaptability.

7. Innovation

A resilient world would place an emphasis on learning, experimentation, locally developed rules, and embracing change.

A resilience approach fosters and encourages novelty and innovation. Our current way of doing things is more about getting better in a decreasing range of activities. Indeed, the current system is mostly about providing subsidies not to change, rather than assistance to change. Drought assistance and flood relief obviously have a humanitarian component, but if they merely perpetuate doing things in the same way they are working against adaptability. A resilient system would subsidize experimentation – trying things in different ways – and offer help to those who are willing to change. Enabling innovation is an important way of creating space. Resilience-thinking is about embracing change and disturbance rather than denying or constraining it. When a feedback loop begins breaking rigid connections and behaviors, new opportunities open up and new resources are made available for growth. A resilient system is open to this, whereas our existing approach is more likely to close down those opportunities.

8. Overlap in Governance

A resilient world would have institutions that include “redundancy” in their governance structures and a mix of common and private property with overlapping access rights.

Resilient social-ecological systems have many overlapping ways of responding to a changing world. Redundancy in institutions increases the response diversity and flexibility of a system (Ostrom, 1999). Such an institutional arrangement fosters a strong awareness and response to cross-scale influences. Totally top-down governance structures with no redundancy in

roles may be efficient (in the short term), but they tend to fail when the circumstances under which they were developed suddenly change. More “messy” structures perform better during such times of change.

Access and property rights lie at the heart of many resource-use tragedies. Overlapping rights and a mix of common and private property rights can enhance the resilience of linked social-ecological systems (Dietz et al., 2003).

9. Ecosystem Services

A resilient world would include all the unpriced ecosystem services in development proposals and assessments.

Many of the benefits that society gets from ecosystems are either unrecognized or considered to be “free” (e.g., pollination, water purification, nutrient cycling, and the many others identified by the Millennium Ecosystem Assessment, see www.millenniumassessment.org). These services are often the ones that change in a regime shift and are only recognized and appreciated when they are lost. They are ignored in purely market-driven economies (which, therefore, are inefficient, according to economists’ own definition of market efficiency).

4 Examples of applying resilience thinking in practice

Until now, we have shown the complex theory of resilience and the attempts to translate it in a way that can be used meaningfully by governance, especially by governance for SD. Although it may still appear to be very abstract, we try to get “back on the ground” with this chapter, in which we describe examples of applying resilience thinking in practice.

The purpose of this chapter is therefore very straightforward: we want to suggest three practical illustrations of what has been analysed so far in the course of this quarterly report.

In the first instance, we analyse the approach taken by the so-called **climate change adaptation discourse** and its linkages with the resilience framework. In the second case, we present a European case for resilience in practice: the **Kristianstad Water Vattenrike**, a wetland in southern Sweden that showed problems with loss of wet meadows, decline of water quality, and a disappearing wildlife habitat. Finally, a case from Australia is presented: the **Goulburn-Broken Catchment** from the State of Victoria.

4.1 Climate change adaptation policies and resilience

In this first example, we use as our main source – and reading suggestion – a very interesting article by Adger et al. that, in 2011, analysed a number of policy responses to climate change as related to the enhancement of resilience in those social-ecological systems.

The article suggests that many of the response strategies, analysed in the context of climate change adaptation, run the risk of reducing system resilience if not carefully conceived and implemented. Hence, it shows that there are definite trade-offs between policy objectives focussed on efficient and effective adaptation (narrowly defined) and those strategies, which seek to retain resilience by investing in the underlying capacity to adapt both to climate and to other stresses that affect social–ecological systems.

In the case of climate change, it is known that this will inevitably cause shocks and disruptions to societies in many ways. Therefore, Adger et al. (2011) concluded that adaptive capacity will be needed, and this will require social–ecological sources of resilience for dealing with the challenges, for recombining experiences, and for creating innovation and ways forward.

The next box, which we decided to show integrally as it is presented in the mentioned article, is a very interesting way to appreciate the study and gives an overview, not only on the cases, but also particularly on the resilience categories utilized. Also notable is the type of policy responses chosen case by case, and what actually has been classified in terms of *enhancing* or *reducing* resilience.

Nine examples are taken in account in this article, all of which were already thoroughly and scientifically analysed by 18 different studies written between 2001 and 2010 (which we report as a table at the end of this subchapter). These 18 studies analysed nine different regions showing a wide geographical representation: USA, northeast Brazil, Canadian Prairie agro-ecosystems, Cayman Islands, British Columbia (Canada), Kenya, Brazil, UK, and Uganda. Consequently, a range of different problems and issues are portrayed from these regions. These issues vary from: expansion of biofuel

production, drought, variable rainfall, tropical storms, pine beetle infestation, drought/flood/disease incidence, water quality and supply, coastal change, fluctuating lake levels.

Box 4.1: Resilience and climate change adaptation policy responses

System Stresses	Sources of Resilience	Active Responses	Effects on resilience	
			Enhancing	Reducing
Expansion of biofuel production, USA ²⁶⁻²⁸	Existing (historical) institutions for soil and land conservation from dustbowl era; Growing concern over water availability and quality Market liberalization: access to Brazilian ethanol from sugarcane	Public actions: Renewable Fuel Standards & Energy Policy Act; Subsidization of ethanol industry Farm-level actions: Expansion of corn acreage, increase in input use, decrease in soybean acreage		Loss of crop diversity; increased risk of erosion and aquifer depletion, decline of soil conservation practices; Infrastructure for new corn-based industry reducing flexibility for alternative fuel development; Increased food insecurity and price volatility with trading partners; Increased global risk of covariate climate shocks in energy and grain sectors
Drought, Northeast Brazil ²⁹	Lessons learned from past drought events; social networks; social security payments, local and international NGOs	Public actions: humanitarian relief; crop insurance; seed distribution; irrigation schemes Private actions: livelihood diversification; agricultural risk management; patron-client relationships		Reliant on outside assistance; increasing financial costs competing with other public priorities; emergency investment rather than development and continued vulnerability to other disturbances
Variable rainfall, Canadian Prairie agro-ecosystems ^{30,31}	Experience with drought from the 1930s; experience with minimum or no-tillage and with drainage practices; learning from a wide variety of farm-level responses to weather variability; use of local associations and support networks	Public actions: crop insurance; income stabilization programs; drainage regulations; environmental farm plans Farm-level actions: coping responses; increasing options; decreasing costs; turning to government assistance		Loss of landscape diversity and crop diversity; reliance on technology and government programs, rather than local knowledge and ecosystem services
Tropical storms, Cayman Islands ³²	Recurrent exposure to hazards within living memories; Experiences of neighboring countries reveal importance of preparedness; Annual learning exercise in reviewing the last years hurricane plan and its implementation; Recognition of the importance of key utilities and services in enabling the society to function—these are prioritized in recovery process; Preparedness support for all members of society provided - avoids social exclusion and ensures wider participation in recovery	Public and private actions: Formal government institutions supported collective action by government, private sector and NGOs to motivate individual preparedness action Resulted in a semi-formal committee that now manages hurricane response and broader risk management	Increasing awareness among population of weather-related risks and the importance of individual as well as collective responsibility in preparedness	Growing dependence on multi-national corporations (esp. banks) to support recovery could reduce economic diversification and hence longer term adaptive capacity
Pine beetle infestation, Western Canadian ^{33,34}	Past industry experience with market volatility; government (uncorrelated) income diversity; labor mobility	Public actions: increased harvest rates; income compensation programs; burning to create a buffer; awareness and monitoring programs		Loss of landscape diversity; increased flooding; disturbance of commercial salmon habitat; decreased labor mobility

System Stresses	Sources of Resilience	Active Responses	Effects on resilience	
			Enhancing	Reducing
Drought, flood, disease incidence, Kenya ³⁵⁻³⁷	Long experience with drought; social networks and new ways to access social capital both locally and beyond	Industry actions: selective salvage coupled to market demand; reconfiguration of mills; market development for 'beetlewood' Public actions: water development; infrastructure development; increasing privatization of land; group ranches Private actions: move livestock in new ways and to new places; diversity livelihoods; sell land, livestock; move to urban areas		Reduced ability to move; loss of landscape complexity; increases in socioeconomic differentiation; poor have less ability to adapt; increased poverty; responses dependent on outside assistance
Water quality and supply, Brazil ^{38,39}	National networks of local committees; local buy-in; local participation and knowledge; technical assistance	Public actions: Decentralization of water management to watershed level	More equitable, transparent and informed decision making; management and resources are local; continuity in membership; expanded management focus to include all development issues	Political control leading to changing water management objectives; focus on economics of water use at expense of the environment and equitable development
Coastal changes UK ^{40,41}	High adaptive capacity; long-standing planning laws and experience with observed incremental changes and extreme events	Community and regional and national government responses in advance of much anticipated change	Shoreline management planning has enhanced community resilience in areas where community coherence is already high and where communities desire to retain autonomy and decision-making	Lack of control by many communities reduces the perception of efficacy and fairness. Long-term policies and strategy for compensation and other mechanisms still to be finalized
Fluctuating lake levels, Uganda ^{42,43}	Ecological diversity of lake and wetland system offers a diverse range of livelihood options Social capital of lake-shore populations, especially links to people away from the lake region	Public actions: Introduction of co-management institutions and enforcement of fishing regulations. Private actions: changing fishing practices; land-based livelihood diversification		Active fishing methods lead to overfishing; Livelihood diversification is vulnerable to long-term variability, for example, extreme rainfall and flooding events; Tensions between survival and maintaining livelihood resilience and the differing goals of lakes-shore dwellers and government agencies threaten the effectiveness of co-management

Source: Adger et al. (2011)

These nine examples were chosen to illustrate a range of problem-framing and timescales of policy responses. All policy responses were of course subject to multiple stresses and multiple reasons for implementation at the time. In this analysis, together with negative or positive impacts on resilience, three key classes of characteristics were taken into account: (1) governance, (2) sensitivity to feedbacks, (3) problem framing.

Firstly, in terms of governance, as we also showed in chapter 3, it is understood that **governance structures have direct implications for the level of flexibility in responding to future change as well as variation in local contexts.**

The second class of key characteristics – sensitivity to feedbacks – showed that in order to evaluate the influence of adaptation activities, there must be sensitivity to changes, or feedbacks, in the system. In this sense, **sensitivity to feedbacks relates both to the timing as well as where these feedbacks occur.**

Therefore, **learning is more likely if feedbacks occur soon relative to action, and if those most affected by feedbacks are those responsible for the action.** Slow feedbacks, those that are spatially distant, or those that are masked by short-term gains in economic or productivity measures, are less likely to result in changes in the response. However, sensitivity to feedbacks is valuable only in relation to the ability of an actor to respond to those feedbacks. Without this ability, there is no capacity for learning and for changing actions in the future.

Thirdly, **the way in which a problem is conceptually framed determines the way in which responses are identified and evaluated and therefore influences the range of response characteristics.** Problem framing and the urgency of the perceived threat influence planning and implementation horizons. Narrow technological responses are associated with near-term time response horizons.

Box 4.2: List of articles on CC adaptation policies

Expansion of biofuel production, USA

- Farigone J., J. Hill, D. Tilman, S. Polasky and P. Hawthorne. 2008. Land clearing and the biofuel carbon debt. *Science*, 319, pp.1235-1238.
- Hill J., E. Nelson, D. Tilman, S. Polasky and D. Tiffany. 2006. Environmental, economic and energetic costs and benefits of biodiesel and ethanol biofuels. *PNAS* 103, pp.11206-11210.
- Solomon B. 2010. Biofuels and sustainability. *Ann New York AcadSci* 1185, pp.119 -134.

Drought, Northeast, Brazil

- Nelson D.R., T.J. Finan. 2009. Praying for drought: persistent vulnerability and the politics of patronage in Ceara', Northeast Brazil. *Am Anthropol* 111, pp.302-316.

Variable rainfall, Canadian Prairie agro- ecosystems

- Sauchyn D.J., E. Barrow, R. Hopkinson and P. Leavitt. 2003. Aridity on the Canadian Plains: Future Trends and Past Variability. *Prairie Adaptation Research Collaborative Summary Document No.03-01*. Available at: http://www.parc.ca/research_summaries.htm. (Accessed July 14, 2011).
- Tarnoczi T.J., F. Berkes. 2010. Sources of information for farmers' adaptation practices in Canada's Prairie agro-ecosystem. *Clim Change* 98, pp.299–305.

Tropical storms, Cayman Islands

- Tompkins, E.L. 2005. Planning for climate change in small islands: insights from national hurricane preparedness in the Cayman Islands. *Global Environ Change* 15, pp.139-143.

Pine beetle infestation, Western Canadian

- Parkins, J.R., N.A. MacKendrick. 2007. Assessing community vulnerability: a study of the mountain pine beetle out-

break in British Columbia, Canada. *Global Environ Change* 17, pp.460-471.

- Ruitenbeek, H.J., C.M. Cartier. 2007. *A Practical Approach to the Use of Environmental Economic Valuation in Socio-Economic and Environmental Assessment Decision-making Frameworks in BC*. Victoria: BC Ministry of Agriculture and Lands.

Drought, flood, disease incidence, Kenya

- Galvin, K.A. 2007. Responses of pastoralists to land fragmentation: social capital, connectivity and resilience. In: Galvin, K.A., R.S. Reid, R.H. Behnke, N.T. Jr. Hobbs, eds. *Fragmentation in Semi-arid and Arid Landscapes: Consequences for Human and Natural Systems*. Dordrecht: Springer, pp.369-390.
- Thornton, P.K., S.B. Burnsilver, R.B. Boone, K.A. Galvin. 2006. Modelling the impacts of group ranch subdivision on agro-pastoral households in Kajiado, Kenya. *Agric Syst* 87, pp.331-356.
- Little, P.D., H. Mahmoud, D.L. Coppock. 2001. When deserts flood: risk management and climatic processes among east African pastoralists. *Clim Res* 19, pp.149-159.

Water quality and supply, Brazil

- Abers, R.N. 2007. Organizing for governance: Building collaboration in Brazilian river basins. *World Dev* 35, pp.1450-1463.
- Lemos, M.C. and J.L.F. de Oliveira. 2004. Can water reform survive politics? Institutional change and river basin management in Ceará, Northeast Brazil. *World Dev* 32, pp.2121-2137.

Coastal changes, UK

- Few, R., K. Brown and E.L. Tompkins. 2007. Climate change and coastal management decisions: insights from Christchurch Bay, UK. *Coast Manage* 35, pp.255-270.
- Tompkins, E.L., R. Few and K. Brown. 2008. Scenario-based stake-holder engagement: incorporating stakeholders preferences into coastal planning for climate change. *J Environ Manage* 88, pp.1580-1592.

Fluctuating lake levels, Uganda

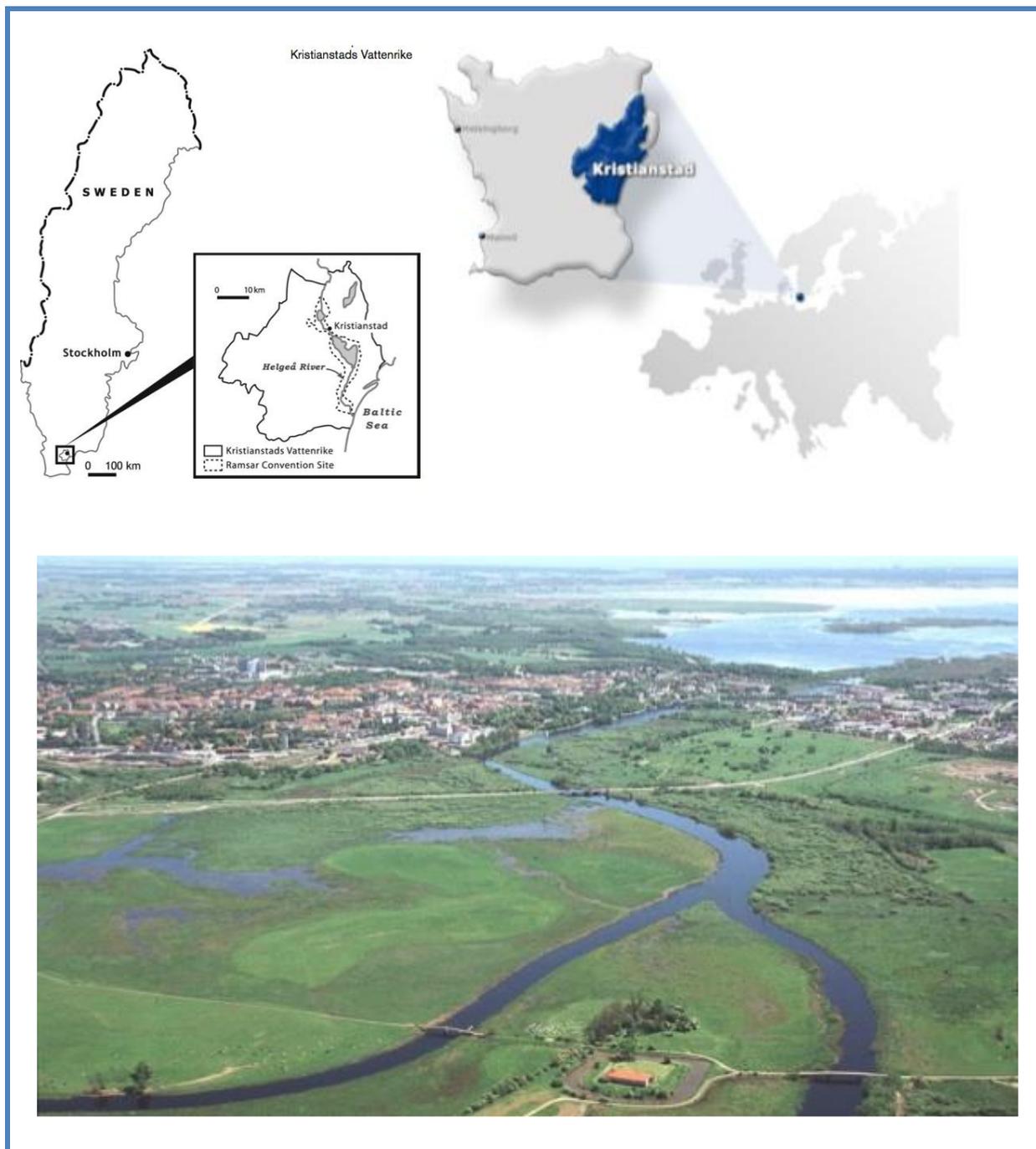
- Goulden, M. 2006. *Livelihood diversification, social capital and resilience to climate variability amongst natural resource dependent societies in Uganda*. PhD Thesis, School of Environmental Sciences, University of East Anglia, Norwich.
- Conway, D., E. Allison, R. Felstead, M. Goulden. 2005. Rain-fall variability in East Africa: implications for natural resources management and livelihoods. *Phil Trans R Soc A* 363, pp.49-54.

4.2 A case from Sweden: Kristianstad Vattenrike

In this second example, we use as our main source a case study that is presented in Walker and Salt (2006) in the fifth chapter, which considers the experience of one of the most advanced European member states in terms of SD: Sweden. The case observed is called “Kristianstads Vattenrike”, which in English means “The Rich Wetlands of Kristianstad/Water Kingdom”.

This area is a 35-km-long wetland area surrounded by cultivated landscape in the south of Sweden, and includes the lower catchment areas of River Helge å and the coastal areas of the bay Hanöbukten, a part of the Baltic Sea. The River Helge å flows from upstream forests through agricultural land, lowland lakes and wetlands, and passes straight through the town of Kristianstad, which is the regional capital with about 30,000 inhabitants. Its history (please see the box below for a complete description) goes back to its establishment in 1614 by the Danish king Christian IV, who used the surrounding wetlands as a defence against his enemy, the Swedes.

Box 4.3 Kristianstads Vattenrike



Sources: Walker and Salt (2006), Kristianstad Municipality, Magnusson (2004)

The Kristianstads Vattenrike is a semi-urban area of high biological and cultural importance in southeastern Sweden. Kristianstads Vattenrike includes Sweden's largest areas of flooded meadows used for **grazing** and **haymaking**. Many of the unique values of the area depend on these activities and the annual flooding of the Helge å River. The Kristianstads Vattenrike provides a range of important ecosystem services, including the filtering of nutrients from water flowing to the coastal area of the Baltic Sea, recreational spaces, provision of significant habitat for a range of wildlife (including the symbolic white stork), and maintaining the cultural and agricultural heritage of the landscape. The area also holds the largest groundwater reserve in northern Europe. The area was

designated to have international importance by the *Ramsar Convention on Wetlands* in 1975, and was recently accepted by *UNESCO* to become a Man and Biosphere Reserve.

As with many regions around the world, a major part of this area's development involved the **control of water levels and flows**. A number of events were particularly relevant for changing the situation of the area. The most relevant ones are here reported as follows in order to give an idea of the linkages between human actions and ecosystems:

- In 1774, local farmers dug a drainage ditch to the sea in order to prevent the annual flood from damaging their land. Unfortunately, the spring flood of 1775 was so severe that it transformed the ditch into a new channel from the Helge å River to the sea. This venture lowered the water level in the water system by more than half a meter.
- In the 1940s, the wetlands came under further threat with the building of embankments and dredging projects to control the river. The aim of this work was to speed the flow of water through the wetlands and to prevent flooding, which resulted in lowering the water system by an additional third of a meter. Several small lakes between Lake Hammarsjön and the sea disappeared in the process. Growing urban sprawl and the construction of roads further fragmented the natural landscape.
- In 1941, the situation grew so dramatically that, also due to untreated sewage from industry and households being poured into the river, the City of Kristianstad was forced to stop taking its drinking water from the Helge å River.
- After World War II there was a great increase of fertilizer usage.
- In 1966, the local municipality established a garbage dump on the wet grasslands nearest to Kristianstad and decided to embank wet grasslands farther south of the city to open up permanent agricultural land.
- In 1974, the Municipality of Kristianstad took on the project of restoring two local lakes by removing the reeds and other plants that were choking them.
- In 1975, a thirty-five-kilometer stretch of the wetlands along the lower Helge å River was declared a Ramsar Convention Site.

Despite several conservation efforts, studies undertaken during the 1980s indicated that the values of the lower Helge å River and the Ramsar wetland continued to decline. This was linked to the fact that flooded meadows used for haymaking and grazing had decreased dramatically due to the abandonment of these management practices. If mowing ceases, the flooded meadows are overgrown by reed, sedge, and willow, as a stage in the ecological succession from flooded meadow to forest. To maintain the wetland, therefore, the grazing and mowing of the flooded meadows needed to continue. These flooded meadows are not an ecologically stable state. The desired regime of this social-ecological system is a cultural landscape with cultivation as an integral component. Without the grazing management, the ecosystem progresses to its stable equilibrium, a wooded system without flooded meadows (and without the wildlife dependent on those flooded meadows).

During this time, a curator of natural history in the Kristianstads County Museum, named **Sven-Erik Magnusson**, began studying the Ramsar Convention Site and found that where grazing and haymaking were still practiced, the unique cultural values and natural values were being maintained; however, where they had been abandoned, these values were in decline.

Together with the Bird Society of North-Eastern Scania (BSNES) and by pooling their experience and knowledge, Magnusson convinced the County Administrative Board and National Forestry Board, the bodies responsible for managing the flooded meadows in protected areas, that **these ecosystems needed more than just protection - they required active management and a reinstitution of traditional agriculture to sustain the natural values of these areas**. In other words, the cultural history and continuous use of the wetlands for grazing and haymaking was linked to the ecological qualities for maintaining a rich bird habitat.

In short, they needed **high adaptability** in order to manage the resilience of the flooded meadow regime and to reduce the strong tendency of the ecosystem to move to its equilibrium state as a forest.

Magnusson learned the **importance of linking the knowledge and experience of actors at different organizational levels**. He was aware of different people and groups operating at different levels in a number of activities (i.e. creating inventories, running monitoring programs, carrying out restoration, attempting to develop improved land use and management practices). He was also aware that the groups undertaking these activities were frequently unaware of each other. He therefore built up the Ecomuseum Kristianstads Vattenrike (EKV), as a forum in which the different actors and groups with a stake in Kristianstads Vattenrike were given the opportunity to meet and exchange ideas and values, and develop a shared understanding and vision for the future of the region. To garner support for the EKV, Magnusson **focused on specific individuals in key organizations** that had some interest in Kristianstad and its surrounding wetlands. With their support and participation, the EKV took form as a body that would play an important role in conflict resolution, information sharing, and coordination. Then, he found support and involvement from a number of other groups including the County Administrative Board, the BSNES, and environmental and farmer associations. **The individuals representing these groups became the nodes of an emerging social network**.

The EKV subsequently **developed into a flexible and collaborative network with representatives from several levels of society, from local to international** (Olsson et al. 2004). It was involved in numerous interventions since its inception. In collaboration with the WWF, bird societies, the Swedish EPA, and the County Administrative Board, the EKV compiled a number of ongoing inventories including the mapping of reserves, cultivated areas, bird populations, and nutrient levels. **The results were communicated to a variety of actors, including the general public, using a wide range of methods**. It is understood that **creating such feedback loops is a prerequisite for managing complex systems sustainably**.

The EKV maintains a close collaborative relationship with the farmers, **making use of their knowledge and understanding of agricultural practices that have often been developed and passed on from generation to generation**.

The existence of collaborative networks across stakeholder groups at the municipal level was crucial for this process to have taken place. Mutual trust already existed, and this new problem/crisis/opportunity was turned into a win-win situation.

Box 4.4 A governance success: Diversity Assists in Managing for Complexity

The success of the EKV in managing the wetland ecosystems of the lower Helge å River has a lot to do with its structure and function. The EKV is part of the municipality's organization, and reports to the municipality board. However, it is not an authority and has no power to make or enforce formal rules.

By serving as a forum that brings together individuals and organizations to discuss emerging issues, build consensus, provide feedback, and share views, the EKV serves a valuable role in building trust and enhancing the resilience of the social-ecological system that is the KV. The very diversity of its membership is a significant part of its effectiveness in dealing with the complexity of the system.

Depending on the type of problem arising, various affected people are gathered together by the EKV in order to be part of the process of solving the problem. Thus, it acts as a facilitator and coordinator of human capital in such an event. The actors are part of the planning, implementing, monitoring, and evaluating phases of the learning process. Management practices emerge and are revised as they are implemented. In addition to this, there are regular meetings of a reference group within the EKV to produce mechanisms for conflict management. The idea is to bring together representatives of any group involved in activities with links to the KV. This builds trust among the representatives, an essential component to the success of the collaboration process. If discussions on collaboration are only initiated once a conflict has arisen, it's much more difficult to reach consensus. Formal agreements and action programs emerge from these collaborative processes. These in turn lead to a change in behavior and practices in order to improve the management of the wetland ecosystems.

The success of the EKV over time would suggest that this approach, often referred to as "open institutions," produces faster and more long-lasting results than making authorities develop rules that force people to change their behavior.

Source: Walker and Salt (2006)

Finally, three main lessons can be learned from this experience:

1. The imposition of a set of rules to protect an ecosystem from the outside (i.e. the establishment of the Ramsar Convention Site) will not ensure the natural qualities of a region will be preserved over time. **One size never fits all, and an understanding of local history and culture needs to be integrated into the management if local values are to be looked after.** For that to happen, local people need to be part of the process.
2. The processes and values that influence the management of an area operate over many scales: local, regional, national, and international. Therefore, for an organization to meaningfully deal with this complexity, **it needs to include representatives from each of these levels in the social network**, which will both contribute to the governance of the system, share that responsibility with other representatives, and provide feedback to their relevant organizations.
3. The formation of the EKV took place because **several organizations were prepared to contribute to a shared vision and build consensus** on how the KV might be managed. However, in its earliest stages, the formation of the EKV was catalyzed by an individual who brought these various actors together. **Leadership is a crucial component in building adaptability and transformability.**

In the box below, we present the history of Kristianstads Vattenrike in more detail:

Box 4.5 History of Kristianstads Vattenrike

There has been increasing pressure on the wetlands and the values they provide since Kristianstad (Christianstad) was established 1614, on a small island near the River Helge å. The Danish king Christian IV used the surrounding wetlands as a defence against the enemy, the Swedes. Using wet grasslands for harvesting hay and grazing is an ancient tradition in Sweden. The size of the lakes and the wetlands in the area of lower River Helge å has been considerably reduced over the last 400 years. In 1774, the farmers of Yngsjö village, near the Baltic coast, dug a ditch leading towards the sea to prevent the annual high water from flooding their land. Unfortunately, the spring flood of 1775 was so severe that it transformed the ditch into a new channel for the River Helge å to reach the sea. This venture lowered the water level in the in the water system more than 35 km upstream. At Kristianstad the water level was lowered from 0,6 to 0,7 meters.

Building embankments and dredging to control the river have further decreased the size of the wetland area. In the late 19th century there was a large embankment project east of the town Kristianstad. The northern bay Nosabyviken, in the lake Hammarsjön, was embanked for agricultural purpose. Nowadays some of the eastern parts of the town are situated on this embanked area, some areas even under the sea level. A dredging project between 1940 and 1945 was carried out to speed the flow of water through the wetlands and prevent the flooding. During the 20th century several other embankments have been made.

The increasingly bad water quality in the early 1900's due to untreated sewage water from industry and households became apparent by many public complaints and the fact that the city of Kristianstad stopped taking its drinking water from the River Helge å in 1941. In 1964 there was a massive incidence of fish mortality in the area and it is believed that this event wiped out the population of the rare European catfish (*Silurus glanis*) in the river. Because of the bad water quality, people did not find the river and the surroundings attractive. Some companies turned the backyards of there factories to the river and at this time (1960's) the municipality, with support from the county administration board, established a garbage dump on the wet grasslands (Härlövs ängar) close to the west of the town, despite protests from local and national non-governmental organizations for conservation interests. In 1958, the public health committee at the Municipality of Kristianstad described the wetlands as "water infested and unhealthy swamp areas [that] should immediately be cleaned up".

In 1967 there were plans to embank wet grasslands at the shore of Lake Hammarsjön (Håslövs ängar), south of the city, to permanent agricultural land. Among conservation interests there were protests, and for the first time, the county administrative board decided to protect cultivated wet grasslands in this region by establishing a nature reserve. In 1971 there was a presentation of a plan for restoring Lake Araslövssjön and Lake Hammarsjön in order to protect the lakes from becoming overgrown by reed and other macrophytes.

During the 1970's inventories were made by the state, and some parts of the area were declared to be of international interest for nature conservation, cultural heritage, fishing and recreation. In 1975, the 35-km stretch of wetlands along the lower part of River Helge å was designated as having international importance by the Convention on Wetlands, known as the Ramsar Convention. However, despite all the efforts, several inventories and observation during the 1980s indicated that the values of the lower parts of the River Helge å and the Ramsar area continued to disappear, especially due to the fact that the wet grasslands used for harvesting hay and grazing had decreased drastically.

In 1988-89, "we started a discussion how to manage the decreasing ornithological values in the wetlands. We found out that we have to widen the approach, otherwise we should not get any support to our ideas. Very soon we provided overall goals and vision in a holistic approach to wetland management". The objective was to preserve and develop the ecological values and cultural heritage of the area while at the same time making careful and judicious use of them. The name Kristianstads Vattenrike (The Rich Wetlands of Kristianstad/Water Kingdom) was coined. We linked people and on-going projects connected to water in the area into a network dealing with nature conservation, environmental protection, tourism, education, and cultural heritage management. As a tool to explain and to be very concrete in our way of working, we started to build an eco-museum with lots of different visitors' sites spread out in the 35 km long wetland area.

Our work is now an example of cooperation between local-national-international authorities and organisations. The inhabitants in the area are of course key partners. The staff at the Ekomuseum Kristianstads Vattenrike coordinates many of the activities, and the eco-museum office come under the direct supervision of the Chairman of the local municipal executive committee.

Source: Magnusson (2004)

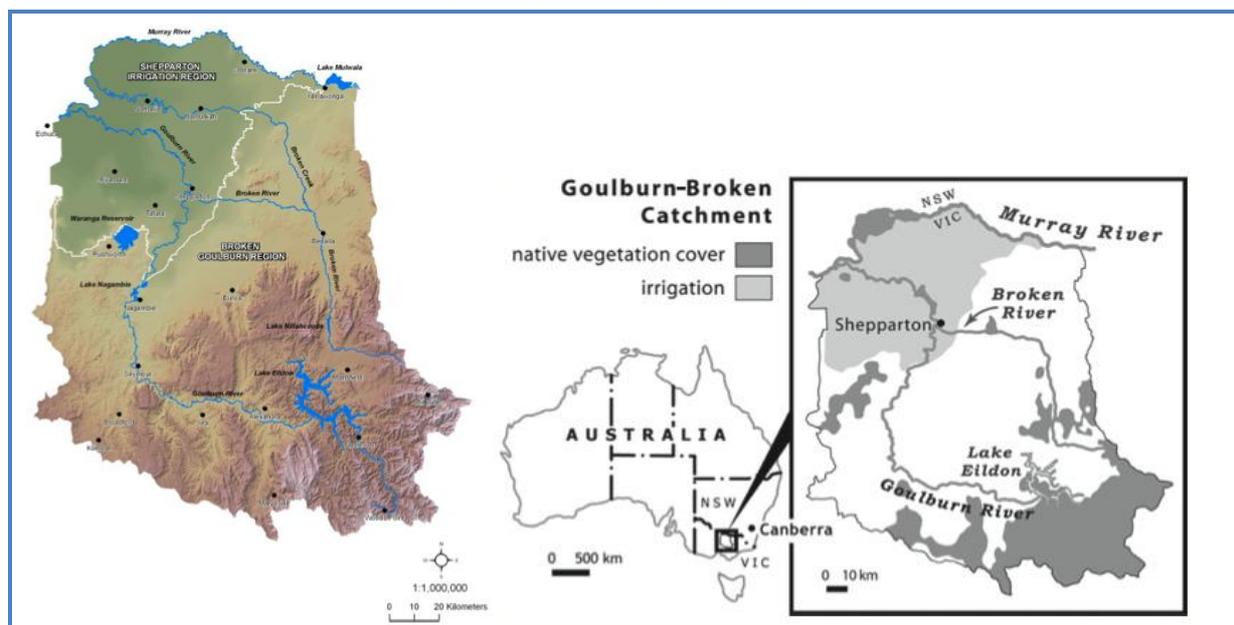
4.3 An Australian case: the Goulburn-Broken Catchment (GBC)

The example of practical application of resilience in Australia is based on two main sources. As already suggested, Walker and Salt 2006's book "Resilience Thinking" represents a primary source for a good understanding of resilience. The second source we suggest here is a paper by Walker et al. (2009), "Resilience, adaptability, and transformability in the Goulburn-Broken Catchment, Australia", that can be found in the online journal *Ecology and Society*. This paper presents a case study of regional resilience assessment that the authors claim to be "the first comprehensive of such assessment" that draws on information from farmers, citizens, researchers, public servants, and publications. The article presents a **resilience-based approach for assessing sustainability**, an approach that is particularly interesting for our report in showing the practical application of resilience thinking.

The Goulburn-Broken Catchment (GBC) is one of Australia's most productive agricultural heartlands. It's also among the most intensively studied catchments. More is known about its biophysical function than just about anywhere. From these studies we can provide some basic information on the region.

The GBC covers 2.1 million hectares in the Murray-Darling Basin (Box 4.6) and is a sub-catchment of the Murray-Darling Basin, Australia's largest and most important river system. Aboriginal people lived in the catchment for millennia before colonization around 1830. The current population is 190,000 people (3% indigenous). The upper, mountainous or hilly catchment (900,000 ha) is more than 50% forested. The mid catchment (1 million ha) of riverine plains, low slopes and foothills has less than 20% of native vegetation cover, which is highly fragmented, and the rest is used for dryland cropping and grazing. The Shepparton irrigation region is on riverine plains adjacent to the Goulburn and Murray Rivers in the lower catchment (about 500,000 ha) with about 2% native vegetation cover and 300,000 ha used for irrigated dairy and fruit production. It is a very productive region, and a major contributor to the economy of the state and the nation.

Box 4.6 Goulburn-Broken Catchment



Sources: Goulburn Broken Catchment Management Authority; Walker and Salt (2006)

Walker and Salt (2006) defined this highly productive region as a region with frighteningly little resilience, where the farmers, and the local communities that depend on the prosperity of the farmers, can continue to function as long as there are no major shocks to the system. Furthermore, their underlying expectation is that *they want to continue doing things the way they've always done things*. Consequently **they have thus far opted to fix up short-term problems rather than address the larger systems-wide issues.**

The main issues in the region are therefore well expressed in synthesis as follows:

- **Past clearing of native vegetation** has caused saline water tables to rise, threatening crop production. Groundwater pumping is necessary but leads to discharging salt into the Murray River at levels that can be unacceptable to downstream users. The recent drought has reduced the immediate threat of rising water tables, but resulted in insufficient water for irrigation. Climate change threatens the future viability of irrigation.
- **Water storage, together with unseasonal releases of water for irrigation**, is degrading the ecological functions of river channels, floodplains, and wetlands, and reducing their values to humans.
- **Application of nitrogenous fertilizer and leguminous plants** are lowering soil pH to the extent that soil health is declining in some areas.
- Native dryland vegetation is sparse, fragmented, and in poor condition, and many **native species are threatened.**
- **Energy costs are an important driver** in the system. If carbon emissions are capped or taxed, the intensive agricultural sectors may become economically unviable. Similarly, salinity outputs from the region to the Murray River are already capped, but salinity control through pumping into evaporation basins is also energy intensive.

However, the region is not just vulnerable to biophysical shocks. It has pinned its hopes on a narrow set of commodities. The changing economic environment means that the catchment's enterprises have limited capacity to absorb shocks. Horticulture and dairy are becoming increasingly vulnerable within a changing global market.

The experience in the 1980s – please see **Box 4.7** for a brief history of the region – was a triumph of the region's response to the crisis of the 1970s: the capacity to engage its own community and create the local networks and institutions was enhanced and this has enabled the region to sustain its productive base and regional vitality. It developed high **adaptability**. The flip side of that same response was a failure to acknowledge fully the underlying cause of the problem and to begin to explore alternative futures for the region. It failed to enhance its **transformability**. Rather than consider the alternatives, all efforts were put toward getting back to business as usual. Working smarter and harder was thought to be the solution. In fact it was only reinforcing the problem. Consequently, this failure has set the region up for even bigger problems down the line.

The Goulburn-Broken story demonstrates the critical importance of understanding the underlying variables that drive a social-ecological system, knowing where thresholds lie along these variables, and knowing how much disturbance it will take to push the system across these thresholds.

To ignore these variables and their thresholds, to simply focus on getting better at business as usual, is to diminish the resilience of the system, increase vulnerability to future shocks (droughts, wet periods, and economic fluctuations) and reduce future options. Being more efficient is not by itself a pathway to sustainability. Because resilience was not being consciously factored into the management of the region, greater production efficiency has actually reduced the possibilities of the system being sustainable.

In conclusion,

“(...) the way forward is not clear or easy. A sustainable future involving transformation will depend on how much land is re-vegetated, the pattern of wet periods that may be experienced while this vegetation is establishing and the region’s capacity to diversify its economic activity in completely novel (non-irrigation) ways. Yet, there is reason to hope. The community is aware of the problems and has developed a significant capacity to work together. That capacity might be the critical factor in this social-ecological system’s resilience as it faces the future” (Walker and Salt, 2006, p.52).

Box 4.7 A brief history of the Goulburn-Broken Catchment

The first occupants of the region were Aborigines. They have been present in the region for at least eight to ten thousand years (and probably much longer). The land was covered by open grassy woodland maintained by periodic fires. The population densities of Aboriginal people in the lower catchment, concentrated along the rivers, wetlands, and streams, were among the highest in Australia, testament to the area’s high natural productivity. Back then the water table was somewhere between twenty to fifty meters below the surface.

The Europeans saw the rich riverine soils of the lower catchment as an excellent place to farm, and land began to be cleared soon after settlement in the late 1830s. The proximity of the mighty Murray River opened up the rich possibility of irrigation and intensive agriculture but the inherent variability of Australia’s climate, a land of “drought and flooding rain,” meant that any development was being severely tested by one disaster after another. Broad-scale irrigated agriculture commenced in the lower GBC in the 1880s and few dams were built.

A combination of positive terms of trade, strengthening individual property rights, subsidized pricing of irrigation water, and a period of exceptionally high rainfall between 1950 and 1960 meant boom times for the region. In this period, farmers invested heavily in the expansion of irrigation. Things were going well and they progressively locked themselves into this ongoing development through their investment. Whilst in previous years the extra rain that was received was absorbed by the landscape, the next extended wet phase (occurred between 1973 and 1977) produced a crisis: the shallow water table rapidly rose into the critical upper two-meter zone across more than a third of the region reducing production of dairy pastures and destroying many high-value horticultural crops with 30 to 50 percent of the stone fruit crops being lost. Dairy and horticultural production and processing, underpinning half the regional economy, were under threat and this had a profound impact on local communities, and beyond.

The immediate response was to install groundwater pumps and draw the water tables down to protect the fruit trees. However, since the pumped water was discharged into the Murray, this action merely served to pass the problem up to the scale of the Murray-Darling Basin. Unfortunately, but not unexpectedly, the wider basin was also experiencing deteriorating water quality with the Murray River becoming increasingly salty, and there was a need to coordinate actions across the many sub-catchments.

In 1986, the River Murray Commission was extended to become the Murray-Darling Basin Commission – a state/federal government partnership agency. Additionally, community leaders in the catchment recognized that the water table crisis required a coordinated response. “Landcare” groups were established that worked with a broad ethic of land stewardship, unlike previous single-focus community groups. A coalition of community and industry leaders lobbied at state and federal levels for assistance and proposed a radical model of integrated catchment management based on community decision making: the state government devolved responsibility for catchment management to regional communities in the form of Catchment Management Authorities (CMAs).

Unfortunately, despite thirty years of effort, the Goulburn-Broken is still on the same trajectory it was on in the 1970s when the first crisis hit, locked into a losing battle with rising groundwater and rising salinity. Just as a social threshold has been crossed in the manner in which a region’s natural resources are managed, a biophysical threshold has also been crossed and the catchment is now moving toward a new equilibrium. It exists in a new ecological regime - one it has actually been in since the early 1900s. This new regime has different feedbacks and a new equilibrium level for the water table: the threshold of native vegetation cover that separated the old regime from the new regime was probably crossed about a hundred years ago.

Source: Walker and Salt, 2006

5 Conclusions and reflections

This QR provided an overview on the topic of ‘resilience’ and offered an exploration on its linkages with sustainable development, system thinking and the concept of adaptive governance.

After a concise executive summary, in the second chapter, we considered the theory that stands behind resilience and tried to answer in a condensed manner to the question: “**What is resilience?**” Accordingly, we provided a clarification of the most crucial concepts that define this theory, especially analysing and exploring in detail three key notions: *thresholds*, *the Adaptive Cycle* and *Panarchy*. We also talked about resilience in terms of systems thinking and the linkages with sustainable development. The idea of **resilience as an important tool for sustainable development** was therefore advanced following the analysis from a number of studies suggested during the chapter.

In the third chapter, the resilience thinking framework and its categories were suggested in terms of governance, and especially for SD governance. Therefore, the relationships between society and ecosystems services were briefly examined as an important reason for governance and its necessity to adopt resilience thinking. In this scenario, the concept and key characteristics of the so-called ‘**adaptive governance**’ instance were proposed as a practical means for societies to deal with the complex issues that social-ecological systems are confronted with. Accordingly, we suggested a number of reflections that wanted to portray the ‘resilience thinking’ in practice, concluding with a list of values toward a ‘resilient world’.

In the last chapter, we showed what we called “real-life examples” with the intention to offer a more ‘on-the-ground’ exploration of three particular instances of issues related to resilience. First, we talked about climate change adaptation and its relationships with resilience. Secondly, we suggested the experience in the wetlands in Sweden, and, thirdly, a case of drought and flood from Australia was considered.

Finally, we here reflect on this complex concept not just for offering a few concluding remarks but also with the intention of generating and stimulating discussions:

A first reflection draws from an important observation of reality: *there has always been change and there will always be change*. This points to how do we cope with change? How do societies – that are embedded in ecosystems – cope with change? And especially, when humanity impacts the Earth ecosystems everywhere on the globe, and when climate change is already manifesting and will continue to manifest even more significantly, how does humanity cope with change?

As portrayed in this Quarterly Report, humanity has a need for persistence and we found in this need the main link between sustainable development and the resilience-thinking framework. Holling defined **resilience** as “*a measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables*” (Holling, 1973, p. 14). What is also true is that humanity needs to cope with change in a way that enhances its capacity and ability to *absorb change and disturbance and still maintain* its main functions, its identity, and, nonetheless, its existence.

We portrayed the resilience-thinking framework as a crucial tool to enhance sustainable development and especially as an approach that SD governance should consider and make its own.

Although the first reaction of dealing with problems is often and inevitably to *fix the problem* in the *short term* with the most *efficient* measure, **resilience thinking shifts our attention towards systems thinking with the primary intention of understanding the underlying and long-term rooted causes of problems.** We can say that the first step is definitely trying to consider the whole system in which these problems arise and, therefore, to analyse and to describe the number of variables that characterise the social-ecological systems in which these problems are embedded into.

Taking into account time horizons comprehensively is, therefore, undeniably crucial. In this case, we propose an interesting hypothesis that is to be found in the example from Australia. In that instance, Walker and Salt (2006) asked: *“if the early settlers had been forewarned of the problems that would be faced some one hundred years later, and been in possession of the information we now have, would they have made different decisions on how they developed the region?”*. Their reply is: *“Probably not”*. Accordingly, Walker and Salt write that a delay of one hundred years, therefore a large time horizon in human terms, between an action and its consequences makes it difficult to take those consequences seriously. In the same way this is happening for instance with climate change. Walker and Salt say that humans have both high discount rates and an enormous capacity in believing the future will generate solutions to problems that don't have to be faced in the foreseeable future.

Can therefore resilience and systems thinking help in this and other problems very much related with sustainable development? Although very complex and multifaceted, many believe that this way of thinking about and approaching change and social-ecological systems could pave the way for a more sustainable world. A practical way of operationalizing resilience thinking would be much needed and very welcomed are, therefore, the efforts of those that we many times suggested in this report as sources for knowledge and information.

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