## BIODIVERSITY, ECOSYSTEM SERVICES AND RESILIENCE

# GOVERNANCE FOR A FUTURE WITH GLOBAL CHANGES

*Biodiversity, Ecosystem Services and Resilience*

# Governance for a Future with Global Changes

Background report for the scientific workshop
»Biodiversity, ecosystem services and governance – targets beyond 2010«
on Tjärnö, Sweden, 4-6 September 2009.

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# Abstract

This scientific background report concludes that halting biodiversity loss and sustaining ecosystem services for human well-being beyond 2010 requires recognition of the dynamic interplay between biodiversity, ecosystem services and human development in the context of rapid global environmental change.

Biodiversity, through its links to ecosystem services production, is crucial for human well-being, economic development and poverty alleviation. However, biodiversity is in serious decline in Europe, and beyond, as a result of multiple human impacts. Biodiversity constitutes an important component of ecosystem resilience, i.e. the capacity of a system to deal with change and withstand shocks without shifting into a qualitatively different state. Resilience has increasingly been acknowledged as an important factor in determining ecosystems' capacity to continue generating ecosystem services. The factors determining resilience may, however, differ substantially between different ecosystems and governance systems. This, in combination with the dynamic and constant changing nature of ecosystems, underlines the importance of an adaptive governance framework that has the capacity to respond to rapid changes. Management of biodiversity and ecosystem services within such a framework has to be adaptive and flexible, which also calls for greater influence and participation of non-state actors.

A number of case studies featured in the report show that adaptive governance of social-ecological systems is becoming more and more applicable in a world increasingly characterised by rapid social and ecological changes, from local to global scales. Preliminary conclusions include the need for an improved knowledge base, increased use of adaptive management approaches in Europe, capacity building for such management and flexible institutions designed to deal with uncertainty and surprise.

# Table of Contents

# Foreword

## SCOPE AND OBJECTIVES OF THE REPORT

The aim of this scientific background report »Biodiversity, ecosystem services and resilience – governance for a future with global changes« is to support deliberations at the high level conference »Visions for Biodiversity Beyond 2010 – People, Ecosystem Services and the Climate Crisis«, to be held in Strömstad, 7-9 September 2009, hosted by the Swedish EU Presidency.

The report has been commissioned by The Swedish Scientific Council on Biological Diversity, which has the mandate to advise the Swedish Ministry of the Environment on CBD-related matters and in conjunction with the Swedish EU Presidency the particular responsibility of arranging a scientific workshop »Biodiversity, ecosystem services and governance – targets beyond 2010« on Tjärnö in Sweden, 4-6 September 2009. The outcome from the Tjärnö workshop will be directly transferred to the high-level meeting in Strömstad, 7-9 September 2009.

The overall objective of the Tjärnö workshop and the Strömstad conference is to prepare a revision of the Strategic Plan of the Convention on Biological Diversity, and in particular the development of new biodiversity visions and targets following the evaluation of the 2010 Biodiversity Target. The basis for the discussions will be this report on biodiversity, ecosystem services and governance, but the workshop and conference will also draw on the results from the European Commission's conference »Biodiversity Protection-Beyond 2010« (Priorities and options for future EU Policy), Athens 27-28 April 2009, as well as the findings of the following recent reports: the European Commission communication »Mid-term assessment of implementing the EC Biodiversity Action Plan«; the ongoing study on The Economics of Ecosystems and Biodiversity (TEEB 2008); and the recent report »Ecosystem Services and Biodiversity in Europe« compiled by the European Academies Science Advisory Council (EASAC 2009), to which the current report is a complement.

This report was prepared by a working group led by Miriam Huitric of Albaeco, an independent organisation communicating the latest in sustainability science with a focus on nature's importance to society and its economy. The report includes contributions from a large group of national as well as international researchers and other experts. The main contributors have been: The Department of Aquatic Sciences and Assessment at the Swedish University of Agricultural Sciences (sections 2.1 and 2.3.1); the Stockholm Resilience Centre at Stockholm University (sections 2.2, 2.3.2 and 2.3.3, and Chapter 3). All parties have contributed to Chapter 4.

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# Introduction

## CHAPTER 1

The sustainability agenda has changed dramatically over the past decade. Two key reasons are 1) the escalating human pressure on natural resources, biodiversity and ecosystem functions and 2) the rapid advance in Earth system and sustainability science. This has resulted in a growing recognition that people shape all ecosystems and at the same time are fundamentally dependent on natural systems and their biodiversity as the life-support base for human well-being and societal development.

The recent report »Ecosystem services and biodiversity in Europe«, compiled by the European Academies Science Advisory Council (EASAC 2009), concludes that we are living through a period »in which ecosystems are being degraded and biodiversity is being lost at rates not seen in human history« and that there are »fears that this will have significant consequences for the flow of the services nature provides«.

Many argue that we are now facing a historic juncture in which the limits to increased wealth are not the lack of conventional form of capital assets (machines, buildings and infrastructure), but the dwindling resilience of natural capital. Two clear signals of this failure are the loss of vital ecosystem services at a global scale and the far-reaching societal challenges posed by global environmental change. In 2005, the UN Millennium Ecosystem Assessment concluded that degradation of ecosystem services presents a significant threat to achieving the UN's Millennium Development Goals, worsening poverty and causing social conflicts. Hence, managing the natural capital of the planet in a sustainable fashion is no longer just an environmental issue, but instead a societal development and equity issue, and in the long-term a question of human survival. Moreover, and the focus of this report, biodiversity provides individual households, communities, societies and the global community with the resilience needed to deal with social and environmental shocks, including securing a sustained flow of critical ecosystem services. Hence, it is in our own self-interest to account for and nurture this capacity, thereby enhancing the likelihood of continued prosperous social and economic development.

Under these circumstances, there is a growing need to find a new model of societal development – a model that recognises the full significance of biodiversity and the ecosystem services it generates, and that supports the resilience of dynamic landscapes and seascapes.

This report takes the stance that humans are embedded in the global eco-logical system providing ecosystem services. This means that ecosystems cannot be managed as separate entities; instead governance must consider human and biophysical systems as intertwined components, or facets, of inter-dependent social and ecological systems. Chapter 2 covers the links between biodiversity, ecosystem services and global environmental change. Based on the findings of the Millennium Ecosystem Assessment, the provision of ecosystem services needs not only to be maintained but also restored and enhanced; biodiversity management is essential in this context. Furthermore, the role that biodiversity plays in regard to adapting to and mitigating global change will be explored in the context of ecosystem services and the resilience of social-ecological systems.

Although scientists can project some of the future impacts of global change on ecosystems and the services and livelihoods they provide, other effects will surface completely unexpectedly because of limited understanding of the strong interconnectedness of social and biophysical systems. Impacts will occur across many scales, with effects measured across time and space and at different levels of social organisation and administration. Hence, the need arises to consider how well the attributes of institutions and wider governance systems at local to global levels match the dynamics of ecological systems; this is addressed in Chapter 3. The report ends by discussing identified gaps in knowledge to be filled to solve these problems and outlines a number of recommendations for how to overcome the many short-comings in the current environmental governance systems.

Humanity has reached a point that demands a new kind of stewardship of the ecological life-support base and the global commons for sustained human well-being. This daunting task is what this report and the Tjärnö Workshop are about.


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# Biodiversity, Ecosystem Services, Resilience & Human Development

CHAPTER 2

## 2.1. WHAT IS BIODIVERSITY AND WHAT ARE ECOSYSTEM SERVICES?

### *Biodiversity*

One of the most commonly used definitions of biodiversity is from the Convention on Biological Diversity (CBD): »...the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic systems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems«. The different aspects of this definition will be explained below.

For many, biodiversity means number of species. However, diversity within species, or »genetic diversity«, is equally important (see the Baltic example in Box 4) because it impacts the functional and response diversity of a system, as discussed below. Likewise, above the level of species, diversity among ecosystems is of great significance. Several authors (e.g. Hubbell 2001), have criticised the CBD definition on grounds that it lacks the inclusion of abundance and thereby misses the importance of the »quality« or »health« of a species. Others refer to measures that take both species richness and abundance into account as »ecological diversity« (Magurran 2004).

The role played by species diversity is captured in different approaches used to examine ecosystem processes and functions. Two relevant concepts in this context are »functional diversity« (Lawton and Brown 1994) and »response diversity« (Elmqvist et al. 2003). Functional diversity is the diversity of species that perform different ecological functions (e.g. pollination, nitrogen fixation) in an ecosystem, or perform a function in quite different ways (e.g. insect and bird pollinators). These ecological functions are carried out by functional groups or species groupings (e.g. predators, herbivores, decomposers, water flow modifiers and nutrient transporters; see Box 1), with different and often overlapping characteristics in relation to the way they use their physical environment and interact with each other (Walker et al. 1999, Hooper et al. 2005). Response diversity refers to the variability in response of species within functional groups to environmental change (Elmqvist et al. 2003). That is, they all perform the same function, but they respond differently to changes in the environment, diseases, etc. A recent definition (Vandewalle et al. 2008) of functional diversity, as »the variety of characters (traits) found across organisms that dictate their response to, and influence on, ecosystem dynamics«, conflates response and functional diversity, but for the purposes of the current report we separate these two concepts. Response diversity plays a special role in ecosystem resilience, as discussed in section 2.3.4.

Ecosystem diversity includes diversity of levels above taxonomical units. An ecosystem is composed of the organisms that interact with each other, and their interactions with the physical environment, at a given spatial scale. It includes the circulation of energy and matter resulting in a trophic structure. As such, ecosystems function at, and can be considered at, multiple scales.

The concept of ecosystems was proposed to capture the idea of relatively homogenous species assemblages and associated environmental conditions (Tansley 1935). However, ecosystem boundaries are not fixed in any objective way and in reports on ecosystems the boundaries are often chosen for practical reasons having to do with the goals of the particular study. In essence, the potential range of species in an ecosystem is selected by the physical environment (temperature, rainfall, soil), and the actual complement of species is selected through interactions amongst these species (competition, herbivory, symbiosis, etc.) and interactions with the environment (modification of local temperature, soil moisture, nutrients, etc.). Interference with the selected composition of a natural ecosystem (harvesting the plants or animals, removing some kinds of species) causes inevitable changes in the interactions between the remaining organisms, and between them and the environment (e.g. changes in water regulation, nutrient cycling).

An important component of ecosystem diversity is the physical structures built up by species, which form important habitats for many other species, for example, the understorey beneath a well-developed forest canopy or the complex three-dimensional structure generated by reef-building organisms in a coral reef. The abundance and complexity of such structures, sometimes referred to as »structural diversity« (Noss 1990, Poiani et al. 2000), in turn relates to the »connectivity« in the landscape (see Box 1). Connectivity refers to the availability of suitable habitat in the landscape to allow species to cross, or migrate, through the landscape (see Box 1). This is a crucial factor for many functions, such as seed dispersal and pollination, and is impacted by both habitat loss and/or degradation, but also fragmentation of landscapes into patches of remnant native ecosystems. As these fragments become smaller, or too isolated, they lose their function in the landscape, with repercussions for biodiversity across the landscape.

### BOX 1

### THE IMPACT OF SPECIES AND ECOSYSTEM DIVERSITY ON THE POLLINATION OF CROPS IN A MIXED LANDSCAPE

Without pollination, many plant species used for food by man would not set fruit. It is estimated that pollinators are needed in about two-thirds of the world's 1500 crop species, and are directly or indirectly essential for an estimated 15-30% of food production (Kremen et al. 2002). It is not however just the presence of pollinators that matters. Their amount and diversity is also important.

Furthermore, the degree of isolation of a crop field or orchard is another important factor. This is determined by the size of areas unsuitable for pollinators that surround the crop field in question. Such unsuitable areas may be urban areas or large fields with wind-pollinated cereals (e.g. wheat).

A German experiment showed that the seed set of two important crop species, *Sinapis arvensis* and *Raphanus sativus*, mustard and radish, decreased with increasing distance to the nearest natural habitat for wild bees (Steffan-Dewenter and Tscharntke 1999). Furthermore, seed set was positively related to the diversity of pollinators, including both honeybees and wild bees. The authors concluded that connectivity of suitable habitats for wild pollinators is essential to maintain not only abundant and diverse bee communities, but also for securing pollination of economically important crops, and as a side-effect also endangered wild plants.


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## *Ecosystem Services*

Ecosystem services (sometimes »environmental services«, »nature's services« or »ecological services«) are the benefits people obtain from ecosystems (MA 2005). In this respect, ecosystems are living natural capital assets that, if properly managed, produce a flow of vital services to human societies.

There are various definitions of ecosystem services (see Table 1). While all have merit, it is important to note that ecosystem services are only part of a range of processes some of which may or may not become classified as services to humanity.

Concepts similar to ecosystem services have existed for a long time (see Box 2), but it is only with the non-negligible impacts of natural resource depletions (e.g. declining soil fertility, water scarcity and deforestation) that the concept has started to gain a wider public interest and application.

The Millenium Ecosystem Assessment (MA) uses four different classes of ecosystem services: provisioning, regulating, cultural and supporting ecosystem services (see Table 2). Some services, like erosion regulation, can be categorised as both a supporting and a regulating service, depending on the timescale of their impact on people.

***Table 1****. Examples of ecosystem service definitions from ecological, economic and ecological-economic studies (from Vandewalle et al. 2008)*

| TYPE OF STUDY | DEFINITIONS |
|---|---|
| ECOLOGICAL | The conditions and processes through which natural ecosystems and the species that make them up, sustain and fulfill human life. (Daily 1997)<br>The set of ecosystem functions that is useful to humans. Many of these are critical to our survival while others enhance it. (Kremen 2005)<br>The benefits provided by ecosystems that contribute to making human life both possible and worth living. (Diaz et al. 2006)<br>Ecosystem functions that provide benefits to humans, i.e. a human beneficiary (current or future) must be explicit. (Egoh et al. 2007) |
| ECONOMIC | The benefits human populations derive directly or indirectly from ecosystem functions. They consist of flows of materials, energy and information from natural capital stocks which combine with manufactured and human capital services to produce human welfare. (Constanza et al. 1997) |
| ECOLOGICAL-ECONOMIC | Fundamental ecosystem services: services that are essential for ecosystem function and resilience, such as nutrient cycling. These are ultimately a prerequisite for human existence, irrespective of whether humans are aware of it or not. The demand-derived ecosystem services, such as recreational values, are formed by human values and demands, and not necessarily fundamental for the survival of human societies. (Holmlund and Hammer 1999)<br>The benefits people obtain from ecosystems. These include provisioning, regulating, and cultural services that directly affect people and the supporting services needed to maintain other services. (MA 2005) |

## BOX 2

### HISTORY OF THE CONCEPT OF »ECOSYSTEM SERVICES«

One of the first records of the idea of ecosystem services is from Plato (c. 400 BC) who realised that deforestation could lead to soil erosion and the drying up of springs (Daily 1997). The modern ideas of ecosystem services probably began with Marsh (1864) suggesting that Earth's natural resources were not unlimited by pointing to changes in soil fertility in the Mediterranean. Unfortunately, his observations passed largely unnoticed at the time and it was not until the late 1940s that society's attention was again caught by the idea. Three authors, Osborn (1948), Vogt (1948) and Leopold (1949) promoted the recognition of human dependence on the environment in combination with the idea of »natural capital«.

In 1956, Sears brought attention to the critical role of the ecosystem in processing wastes and recycling nutrients. The term »environmental services« was finally introduced in a report of the Study of Critical Environmental Problems in 1970, which listed services including insect pollination, fisheries, climate regulation and flood control. In succeeding years, variations of the term were applied (e.g. »public-service functions of the global environment«, Holdren and Ehrlich 1974; and »nature services«, Westmann 1977) but eventually »ecosystem services« became the standard in the scientific literature (Ehrlich and Ehrlich 1981). The review by Vandewalle et al. (2008) of 208 articles that considered the concept of ecosystem services provides a good overview of studies from the 1960s and 1970s dealing with the loss of services and its consequences, as well as the failure of »human-made« substitutions.

Much of the current understanding of ecosystem services was developed during the 1990s, which saw an explosion of books and articles dealing with and expanding the concept (e.g. Folke 1991, Ehrlich and Ehrlich 1992, de Groot 1992, Folke et al. 1994, Baskin 1997, Costanza et al. 1997, Daily 1997).

Ecosystem services are not produced in isolation, rather, most ecosystems generate a bundle of ecosystem services that co-vary (Foley et al. 2005; see Box 3). A forest, for example, provides both wood and non-wood products, regulates climate and water supply, purifies air and drinking water, prevents soil erosion and supports soil fertility. It also plays an important role for tourism and

***Table 2.** The Millennium Ecosystem Assessment's categorisation of ecosystem services*

- Provisioning services: the products obtained from ecosystems, including food, fibre, fuel, genetic resources, ornamental resources, freshwater, biochemical, natural medicines and pharmaceuticals.
- Regulating services: the benefits obtained from the regulation of ecosystem processes including air quality regulation, climate regulation, water regulation, erosion regulation, water purification and waste treatment, disease regulation, pest regulation, pollination and natural hazard regulation.
- Cultural services: the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences, including cultural diversity, spiritual and religious values, knowledge systems, educational values, inspiration, aesthetic values, social relations, sense of place, cultural heritage values, recreation and ecotourism.
- Supporting services: are necessary for the production of all other ecosystem services. They differ from provisioning, regulating and cultural services in that their impacts on people are often indirect or occur over a very long time, whereas changes in the other categories have relatively direct and short-term impacts on people.

recreation as well as in the aesthetics of the landscape and in some regions it may have a religious value. Ecosystems can only continue to provide these various services if multi-functionality is taken into account in their management. Inappropriate developments such as excessive intensification, mechanisation, over-exploitation of resources, environmental pollution and urbanisation are only some of the factors that increasingly threaten multi-functionality of ecosystems.

While the publication of the MA has stimulated widespread international debate about the importance of the links between ecosystems and human well-being, many important questions remain. These include understanding: how biodiversity links to ecosystem processes and ecosystem services (see section 2.3.2.), how bundles of ecosystem services co-vary in a landscape (see Box 3) and how the scales at which ecosystem services are produced and consumed can be measured.

## BOX 3

## MULTI-FUNCTIONAL ECOSYSTEMS PROVIDE BUNDLES OF SERVICES

Different types of land-use result in different types (and magnitudes) of trade-offs between interacting sets, or »bundles«, of ecosystem services (see Figure 1 below). A natural ecosystem (left) can support many ecosystem services at high levels, but does not necessarily produce a lot of food. An intensive cropland (middle), on the other hand, produces a lot of food, but often at the expense of other ecosystem services, which also threatens the viability of food production from a long-term perspective. A cropland with restored ecosystem services (right), which is explicitly managed to maintain multi-functionality in the landscape (e.g. an agro-forestry system), can nurture a broader portfolio of food as well as other ecosystem services.

While much agricultural development over the past decades has followed the middle trajectory in Figure 1 (e.g. Tilman et al. 2002, Foley et al. 2005), the Tigray project in Northern Ethiopia presents a successful example of how landscape multi-functionality can be enhanced by management. Over the past 10 years, agricultural yields have increased at the same time as more honey and fuel wood have been produced, the ground water level has risen, the fertility of the soil has improved and farmers have become less vulnerable to drought (SNF 2008).

The production system in Tigray is based on maintaining and nurturing the local biodiversity and relies heavily on local knowledge. Active support has been given to promote composting, water harvesting, re-introduction of local grass species and planting of multi-purpose trees. Having transformed an eroded, over-grazed area with dried-out riverbeds, to a highly productive, multi-functional agro-ecosystem, farmers in the area say themselves that they are amazed by the development (SNF 2008).

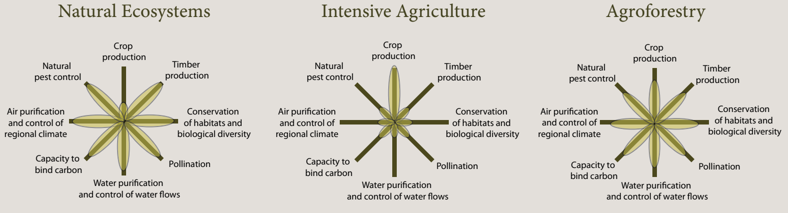



*Illustration: C.Clifstock*

***Figure 1.*** *An illustration of variations in the provision of ecosystem services in ecosystem service bundles with different land uses (adapted from Foley et al. 2005).*

### *2.1.1. Indicators of Biodiversity and Ecosystem Services*

The term biodiversity encompasses a range of different, but overlapping aspects, which makes identifying relevant and measurable indicators challenging (see Box 4).

In 2004, a pan-European initiative called »Streamlining European 2010 Biodiversity Indicators« (SEBI 2010) was launched to develop a European set of biodiversity indicators (Balmford et al. 2005). The authors clearly stated the need for indicators »of biodiversity and ecosystem functions and services that are rigorous, repeatable, widely accepted, and easily understood«. The initiative was tied to the global Convention on Biological Diversity (CBD), which lists eleven »global indicators for assessing progress towards the 2010 target« (UNEP 2003). Both CBD and SEBI 2010 have created global awareness for the need of new biodiversity indicators that can be easily communicated to decision makers. And both initiatives have suggested a set of global to regional indicators of biodiversity, mainly assessing the status of selected rare or threatened species and habitats. Based on these, eight CBD »focal areas« and 16 EU »Headline Indicators« have so far been selected, the latter containing as many as 26 indicators.

There are, however, some drawbacks in their approaches for indicator selection. First, being mainly limited to selected species, the functions, processes and services of biodiversity are not, or only indirectly, considered (Noss 1990, Poiani et al. 2000). Second, indicators need to be applied at suitable spatial scales (e.g. Araujo 2004, EEA 2007) but in reality are often limited to narrow geographical ranges. For example, a species classified as threatened in the Mediterranean region may be naturally absent in Scandinavia, thus, up-scaling of biodiversity indicators for selected rare or threatened species must be related to the species pool at the appropriate spatial scale. Third, there is much evidence that ecosystem services are dependent on functions and processes resulting from a combination of many species rather than single species (e.g. Gren et al. 1995, Bolund and Hunhammar 1999, Strange et al. 1999, MA 2005a, Diaz et al. 2006). For example, the regulation of self-purification in rivers is controlled by a multitude of organisms processing carbon and other components, varying in species composition with region and river type. Fourth, an indicator's suitability may

## BOX 4
### THE CHALLENGE OF MEASURING BIODIVERSITY

The simplest measure of biodiversity is probably the number of taxa per unit area, but even this relatively simple metric contains a number of assumptions and constraints: 1) For some taxonomical groups, the taxonomy is not fully understood making it difficult to count species. 2) It is not always clear at which taxonomic level the quantification should be performed, often a lot of genetic information is missed. For example Johanneson and André (2006) found that the cod and eelgrass species in the brackish Baltic Sea have lower genetic diversity than their marine counterparts. Mapping all genetic diversity with available techniques, however, is not possible and even quantification at the species level is time consuming and requires a high level of expertise. Moreover, higher taxonomic levels than species may also be of importance for conservation purposes. For example, in Sweden the plant family Araliaceae has one genus (Hedera) and one species (*H. helix,* ivy), while the plant family Cyperaceae is represented by more than ten genera of which the genus Carex holds about 100 species. A hypothetical loss of *H. helix* from the country would imply the loss of one species, one genus and one family, while a loss of a Carex species is restricted to just that species. 3) Species-area descriptions do not consider quantities of species. Differences in abundance can be tackled by using a plethora of indices that take both number of species and abundance into account (e.g. the Shannon-Wiener Index) (Magurran 2004).

4) The relationship between number of species and investigated area is not linear (Connor and McCoy 1979). As a consequence, the total investigated area is of importance, as well as the size of the individual sample plots. If too small sample plots are chosen, the number of species per plot may be an artefact of the physical size or spatial patchiness of the taxa present in the investigation area.

Functional diversity can also be quantified in different ways. Among the most common are to map the dominant traits in a community, which according to the »mass ratio hypothesis« by Grime (1998), have a key effect on several ecosystem processes. The dominant traits can, for example, be estimated by the relative abundance of a functional group (e.g. abundance of nitrogen-fixing species). Another important aspect is the degree of functional dissimilarity and complementarity in trait values within a community (de Bello et al. 2008). This can be expressed through various metrics, including functional divergence (Leps et al. 2006) and the number of functional groups (Díaz and Cabido 2001).

differ between ecosystems; for example, habitat area measures are rarely applied (and maybe less useful) for river ecosystems. Fifth, there is a fundamental difference between semi-natural (managed) and natural (unmanaged) ecosystems. While appropriate management is crucial to sustain ecosystem services in the former, the latter usually provides the services without management (depending on the condition). Hence, biodiversity and ecosystem service indicators in semi-natural ecosystems, such as grass- and shrublands, agro-ecosystems or managed wetlands, need to take management practices into account.

Ecological assessments using indicators have a long tradition in both aquatic and terrestrial ecosystems (e.g. Kolkwitz and Marsson 1902, 1908, Pantle and Buck 1955, Friedrich 1990, Holloway 1980, Dufrêne and Legendre 1997, McGeoch 1998), but there are many difficulties involved in agreeing on a common definition of the term »indicator« that is i) applicable over a wide range of ecosystems, ii) useful for both abiotic and biotic indicators and iii) widely accepted and applied by the scientific community. The SEBI 2010 initiative has produced a standard terminological framework for indicators (EEA 2007). Here, a biodiversity indicator serves four basic functions: 1) simplification as it summarises often complex and disparate data, 2) quantification as statistically sound and comparable measures are related to a reference or baseline value, 3) standardisation as they are based on comparable scientific observations and 4) communication as they provide a clear message that can be communicated.

In a study by Feld et al. (2007), peer-reviewed literature in the Science Citation Index Expanded database (time period from 1997 to May 2007) was searched to identify studies addressing biodiversity and ecosystem service indicators using a set of standard indicators of terrestrial and aquatic ecosystems as keywords. The subsequent RUBICODE database was based on 534 studies. Whereas 15–59 references were found for biodiversity indicators in different terrestrial and aquatic ecosystems, very few references directly addressed the ecosystem service indicators, and very few references directly referred to the Millennium Ecosystem Assessment. That said, 425 references could be considered to indirectly address the indication of ecosystem services as most indicators – indirectly or directly – refer to regulating and supporting services. Interestingly, very few (< 6 %) could be linked to provisioning services, such as food and fuel supply, though this could be a result of the focus of the study and not a true reflection of the existence of such indicators. Altogether, less than 2 %

referred to monetary indicators or presented results of the application of monetary inventories.

The main approach to quantifying ecosystem services has been to provide an economic valuation (e.g. Costanza et al. 1997, TEEB 2008). Facing the challenge of SEBI 2010 and the Millennium Ecosystem Assessment, ecosystem (service) valuation has become an integral component of ecosystem indication towards halting the loss of, and sustaining, biodiversity at levels required to maintain their service provision (see TEEB 2008). Gren et al. (1995), for instance, calculated the value of the entire Danube floodplain, mainly with respect to its regulative function, i.e. nitrogen and phosphorous retention: the value was at least 650 million Euros per year. Another example is the Natural Capital Project in the US, a partnership between The Woods Institute for the Environment at Stanford University, The Nature Conservancy and World Wildlife Fund. The Project was launched in 2006 in Washington, D.C. with the aim of producing maps of ecosystem services at the landscape level, assessing their values in economic and other terms and incorporating those values into resource decisions.

Although economic valuations may provide information about the importance of ecosystem services and, consequently, might influence conservation decisions, they tend to be inadequate in conservation management and more precisely in habitat management strategies affecting service provision and biodiversity conservation (Egoh et al. 2007). Some ecosystem services, such as the provisioning services like food, timber and fresh water, are well-defined and routinely included in economic valuations, poverty-reduction strategies and decision-making at large. Regulating services (e.g. carbon sequestration, storm protection and pollination) or cultural services (e.g. recreation and spiritual values), on the other hand, are often over-looked because they are not traded on the market or internalised in traditional cost-benefit analyses. Several researchers have stressed the urgent need to quantify ecological services in other ways than economically, and to develop a measurement of biophysical service units (e.g. Boyd and Banzhaf 2007, Egoh et al. 2007). Furthermore, comparable landscape-scale studies on ecosystem (service) valuation in Europe are still fairly sparse, but urgently needed to monitor ecosystem service values and communicate them to decision makers.

### *2.1.2. Status and Trends of Biodiversity and Ecosystem Services*

In recent years a range of studies, with the UN's Millennium Ecosystem Assessment (MA) at the forefront, have tried to assess the status of ecosystem services from local to global scales. All of the reports presented here (MA 2005, TEEB 2008, EASAC 2009, Harrison et al. 2009) concur that the current losses in biodiversity, and the impact of these losses on the provision of ecosystem services, present a threat to society at a global scale.

The MA investigated the consequences of ecosystem change for human well-being through a scientific appraisal of ecosystem services. The assessment synthesised a wide range of available evidence and investigated options for responses at different scales. At global scales, 60 % of the ecosystem services on which people depend were found to already be over-exploited or threatened due to, for example, damage to habitats, invading species, eutrophication and environmental pollutants. These threats, together with the accelerating changes in world climate, are already today having severe impacts on biodiversity. The results suggest that human activities have changed most ecosystems and threaten the Earth's ability to support future generations.

On a European scale, the trend for biodiversity also points downwards. Despite the EC Biodiversity Action Plan to halt biodiversity loss by 2010 (Commission of the European Communities 2006), it is highly unlikely that the goal will be reached (Commission of the European Communities 2008; see Box 5). The main reason for this is a pan-European habitat destruction that has been ongoing for several decades, and continues, and that the large-scale restorations necessary to reach the goal cannot be achieved within a few years. Another source of problems is invasive species that continue to spread rapidly (DAISIE European Invasive Alien Species Gateway, http://www.europe-aliens.org). One of the few positive trends in European biodiversity and habitat quality is for water habitats and water quality (EEA 2007).

"The Economics of Ecosystems and Biodiversity" (TEEB 2008) concludes that a »business-as-usual« scenario will lead to a continued or even accelerated loss of habitats and ecosystem services. More explicit results of the TEEB scenarios are that by 2050; the loss of biodiversity and ecosystem services will amount to 6 % of global GDP, 11 % of the natural areas remaining in 2000 are expected to be lost due to increased infrastructure and climate change and about 40% of

### BOX 5

### FINDINGS FROM THE EC MID-TERM ASSESSMENT OF BIODIVERSITY TRENDS IN EUROPE

- 50 % of the species of European conservation interest have an unfavourable conservation status
- More than 40 % of European bird species have an unfavourable conservation status
- Up to 80 % of the distinguished habitat types of European conservation interest have an unfavourable conservation status

land currently with low impact is expected to be transformed to intense agricultural land with substantial losses of biodiversity.

Another important review of the state and trends in biodiversity is the policy report by the European Academies Science Advisory Council (EASAC 2009) that concludes that the most pronounced trend over the last century is urbanisation. This has led to a focus on provisioning services, at the expense of services less quantifiable in monetary terms, in particular those associated with complex ecosystems or high biodiversity. Other EASAC observations are: declines in carbon stores that affect climate, and loss of species-rich grasslands and wetlands, with implications for biodiversity. The EASAC report concludes that »sustaining production levels without recourse to natural processes for nutrient cycling and disease and pest regulation will be increasingly difficult and costly«.

A recent study by Harrison et al. (2009) builds on the work of the MA (2005) by collecting evidence on the variety and relative magnitude of the services provided by the main terrestrial and freshwater ecosystems in Europe, in addition to past trends in their status and human use. The MA concluded that the global condition of most services, except for food production and climate regulation, has decreased over the past 50 years (Carpenter et al. 2009). Similarly, Harrison et al. (2009) report that the majority of European services show either a degraded or mixed status for the period 1990 to present, with the exception of an enhancement in: timber production in forests and mountains, freshwater provision, water/erosion/natural hazard regulation, recreation/ecotourism in mountains and climate regulation in forests.

Human use (and demand) of all ecosystem services has increased at the global scale, except for wood fuel, wild foods and freshwater capture fisheries (MA 2005). In Europe, demand for crops from agro-ecosystems, timber from forests and mountains, climate regulation from forests, water flow regulation from rivers, lakes, wetlands and mountains as well as recreation and ecotourism in most ecosystems have increased (Harrison et al. 2009). Also like the MA, fresh-water capture fisheries and wild food in Europe showed decreasing trends in human use.

### *Differences between the European and the Global Assessments*

Differences between the global (MA 2005) and European (Harrison et al. 2009) studies include: increases in the use of wood fuel for bioenergy in Europe, particularly in northern Europe (Wright 2006), decreases in livestock production and decreases in services associated with ecosystems that have considerably decreased in area or habitat quality in Europe, such as heathlands/shrublands and semi-natural grasslands. Hence, general trends at the global level will not necessarily correspond with the same trends at the continental scale in Europe. In addition, some services display varying trends within Europe (Harrison et al. 2009). Food production, for example, shows a mixed trend across Europe after 1990 due to the effect of the last reforms of the EU's Common Agricultural Policy (CAP) and EU rural development policy (EEA 2007). Trends differed in particular between northern, southern and eastern Europe.

### *2.1.3. Driving Forces of Biodiversity and Ecosystem Service Change*

The driving forces that determine present biodiversity patterns and losses can be divided into two main categories: natural and evolutionary drivers, and anthropogenic drivers. The main natural drivers are rates of dispersal, degree of isolation and ecosystem productivity. Important ecological factors are interactions between and within species (e.g. predation, competition and parasitism). The main anthropogenic drivers include excessive nutrient loading of inland and coastal waters, overfishing, land-use change and habitat destruction (e.g. accelerating transformation of land to urban areas) (MA 2005, EASAC 2009). Folke (1996) analysed the human drivers of biodiversity loss and other environmental problems in more depth and divided them further into proximate (e.g. urbanisation, pollution and land-use change) and underlying causes (e.g. structure of property rights, behaviour of financial markets, transfer of knowledge, power relations in society, legal incentives and level of democracy).

In many cases the anthropogenic actions distort the natural dynamics, for example, the transformation of diverse, low-productive natural grasslands to arable fields with monocultures of crops, accompanied by the use of fertilisers and pesticides. In effect, one ecosystem service, crop production, is maximised at the expense of others, for example, biodiversity, water regulation and nutrient retention (see Box 3). Even surrounding areas are affected through fragmentation and pollution, in this case by agro-chemicals, that move into the surrounding landscape.

A final important anthropogenic factor is climate change. It has been predicted that an increase in average global temperature of 1.5 to 2.5 °C, could result in 20 to 30 % of all species going extinct (IPCC 2007). There is mounting evidence that the world's atmosphere is warming with increased changes in the variability of climate, frequencies and intensities of drought, rainfall and major floods and spread and emergence of diseases. These changes are already having significant impacts on many of the world's ecosystems, including coral reefs, tropical forests, ecosystems in the Arctic and Antarctic regions and dryland agro-ecosystems. In addition, these changes will alter the effectiveness of the many reserves and conservation areas that are now fragments in the landscape providing little scope for the species within to migrate in response to climatic changes.

The effects of increased frequencies of extreme weather events is compounded by the fact that we have altered many natural systems so much that their resilience and ability to protect us from disturbance is greatly diminished (e.g. MA 2005). Forests, for example, reduce landslides and floods, in addition to their key role in sequestering carbon and stabilising the climate.

If resilience continues to decrease in social-ecological systems as we strive to increase production efficiencies, the frequency of regional catastrophes will escalate. The ongoing climatic and ecological changes, together with population growth, rapid urbanisation, land-use change and globalisation, are key drivers of human vulnerability to natural disasters. In addition, human population growth has forced people and economic activities to settle in vulnerable areas, such as lowland and coastal areas (Adger et al. 2005).

## *Biodiversity and Threshold Effects*

Land-use change is a common cause of biodiversity loss. As the size of remnant patches gets smaller, the resilience of many of the species populations they contain is reduced. Fluctuations in disturbances (e.g. climatic conditions or predation) that they could previously absorb can now cause local extinctions (e.g. Walker and Meyers 2004).

There is an emerging scientific concern that global warming may trigger regime shifts in ecosystems, that in turn will have feedback effects on the atmosphere and climate system, thereby accelerating climate change. It has been estimated that over the past 150 years ecosystems have provided an immense ecosystem service to humanity by absorbing approximately 50 % of the global carbon dioxide emissions (Canadell et al. 2007, Houghton 2007). Sustaining biodiversity is therefore no longer only an issue of conservation. It is also a precondition for avoiding long-term feedbacks that may cause climate system collapses (Trumper et al. 2009). In other words, protecting biodiversity results in a double dividend: the many vital ecosystem services it provides are central in tackling climate changes that are bound to happen at the same time as they limit changes by absorbing green house gases in the atmosphere.

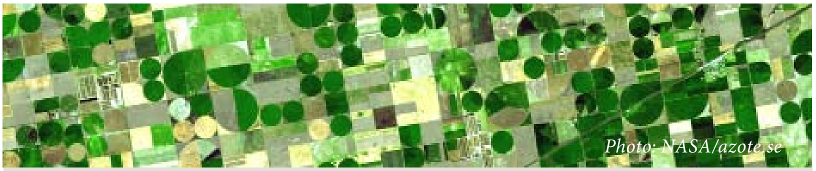
*Tipping points*

Even though global change may appear to be a slow and gradual process on human scales, the Earth might be approaching a number of »climate-related tipping points« in this century (Lenton et al. 2008). Lenton and colleagues list nine regions around the world where human activities could kick-start abrupt and potentially irreversible changes within 100 years. One of these is the Amazon rainforest where the combined effects of global warming and deforestation are projected to reduce rainfall in the region, resulting in dieback of the forest. Models predict dieback of the rainforest to occur under 3 to 4°C global warming within fifty years. The damage will release huge amounts of carbon into the atmosphere, creating a vicious cycle that will worsen both global warming and forest degradation in the region. Another group of researchers have begun the work of identifying the Earth's potential »planetary boundaries«; ecological and geophysical boundaries of the planet that should not be crossed (see Box 6).

## 2.2. WHAT IS RESILIENCE?

Resilience is the capacity of a system (e.g. a community, society or ecosystem) to cope with disturbances (e.g. financial crises, floods or fire) without shifting into a qualitatively different state (Gunderson and Holling 2002). A resilient system has the capacity to withstand shocks and surprises and, if damaged, to rebuild itself. Hence, resilience is both the capacity of a system to deal with change and continue to develop. It covers three key features: persistence, adaptability and transformability (see Box 7 and discussed below).

Whereas our economic and institutional systems tend to assume that development in social-ecological systems is predictable, controllable and follows more or less linear trajectories, science increasingly shows that this assumption is incorrect (Holling and Meffe 1996, Folke et al. 2002). Different systems, from the Baltic Sea (see Box 8) to coral reefs, tropical forests and arid lands, exhibit trends of long periods with seemingly limited change, then sudden periods of abrupt change (Scheffer et al. 2001). Experience suggests that critical ecosystem transitions are increasingly occurring as a consequence of human actions and seem to be more common in human-dominated landscapes and seascapes (Folke et al. 2004).





## BOX 6

### PLANETARY BOUNDARIES: PRECONDITIONS FOR SUSTAINABLE DEVELOPMENT ON THE PLANET

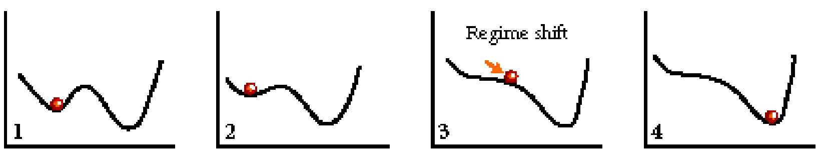
Human activities are now capable of triggering regime shifts in the Earth's system (Steffen et al. 2004). We need to determine the key ecological and geophysical boundaries of the Planet that place humanity dangerously close to a threshold. Around such a threshold even a small additional perturbation can tip the system to a new undesirable and often irreversible state. So far, identified planetary boundaries include nitrogen and phosphorous biogeochemical cycles, ocean acidification, stratospheric ozone, global freshwater use, land-use, chemical pollution and atmospheric aerosol loading, biodiversity and climate change (Tällberg Forum 2008).

In the worst-case scenario, crossing one of these boundaries could result in abrupt environmental change at regional to planetary scales. Effects would include sea-level rises of several metres, a collapse of agricultural systems in dry regions, a total loss of coral reefs and the dry-up of the Amazon rainforest. Identifying these boundaries requires a much deeper understanding of the dynamics of the Earth System and its many subsystems. One challenge is to understand how biodiversity changes that influence the resilience of ecosystem services at local and regional scales can cascade up to influence the sensitivity of planetary boundaries, and therefore resilience at global scales.

Identifying the critical zones surrounding these planetary boundaries and monitoring appropriate indicators can warn if a threshold is being approached. There is, however, a high degree of uncertainty in quantitatively defining planetary boundaries, related to limits in our scientific understanding, difficulties in predicting self-regulating feedbacks and the consequences for a particular boundary of transgressing other boundaries. Nevertheless, this boundary-setting approach opens up several opportunities. It operationalises an Earth System's perspective on global sustainability by considering a group of key interacting parameters, rather than avoiding the reality of complexity by focusing on individual parameters and sub-systems. It emphasises the global scale of the human challenge and captures global-level risks that cannot be effectively dealt with at national and sub-global institutional and governance levels; at the same time incorporating interaction of scales.

The resilience approach to these issues assumes that social-ecological systems behave as complex adaptive systems (Levin 1998). That is, they are self-organising systems. But there are limits to their capacity to self-organise, and if these limits are exceeded their self-organising behaviour propels them towards some new state (sometimes called »regime«, »alternate regime/state« and »domains/basins of attraction«, see Figure 2). The limits to self-organisation are due to the fact that complex adaptive systems have non-linear dynamics, with consequent threshold effects between alternate regimes.

Complex adaptive systems (such as human societies and ecosystems) do not respond to change in a smooth fashion. »Tipping points« occur when the cumulative effects of environmental changes and disturbances reach thresholds that result in dramatic, and often rapid, changes. Accumulated stresses may cause catastrophic shifts so that small events, such as droughts, floods or pest outbreaks, might trigger ecological changes that are difficult or even impossible to reverse. This phenomenon has been observed in ecosystems such as coral reefs, freshwater resources, coastal seas, forest systems and savannah and grasslands (e.g. Scheffer et al. 2001, Walker and Meyers 2004; and Figure 2).




*clear-water lakes* | *phosphorous accumulation in agricultural soil and lake mud* | *flooding, warming, overexploitation of predators* | *turbid-water lakes*

***Figure 2.*** *The »ball and cup« model illustrates resilience loss followed by phase shifts in a temperate lake ecosystem. 1: Original system state. 2: The »stability domain« is affected by various changes in the environment and/or in management practices that reduce the resilience of the system (the cup becomes shallower). 3: A disturbance that previously could be absorbed moves the system into an undesirable state with a loss of ecosystem services. 4: The system is essentially locked in an undesirable state generating fewer ecosystem services to society. The ball resembles the state of the ecological community and the cup is referred to as the »stability domain« or »basin of attraction«. The stable state of the system is at the bottom of the cup but can be moved up along the side of the cup by a disturbance. The shift from one stability domain to another involves passing a threshold (adapted from Deutsch et al. 2003 and Folke et al. 2004).*

## BOX 7

### THREE KEY FEATURES OF RESILIENCE

1. Persistence (sometimes called buffer capacity): the capacity of a system to maintain structure and function when faced with shocks and change (e.g. for a forest or coastal town to withstand the shock of a hurricane);
2. Adaptability: the capacity of people in a social-ecological system to manage resilience through collective action in order to stay within a desired state during periods of change (e.g. the ability to safeguard current food production systems under climate change);
3. Transformability: the capacity to transform in periods of crisis in order to create a new system when ecological, political, social or economic conditions make the existing system untenable (e.g. turning the current financial crisis into an opportunity to transform the global economy and jump start the age of green economics).

If there were no possibility of thresholds or state shifts then there would be no fundamental problem for resource management or governance, because the system would always be smoothly reversible within current technology and resource constraints (e.g. Scheffer and Carpenter 2003; see Figure 3 a). If a mistake was made, or stakeholders were to change their minds (values), there would be no fundamental difficulty in moving to another state of the system. As most social and ecological systems are non-linear systems, however, the likelihood of alternate regimes is high. The existence of alternate regimes is what makes the concept of resilience so important. A shift (intended or unintended) from one to the other can be irreversible (e.g. many salinised irrigation systems), or are reversible, but with a hysteresis effect. Hysteresis effects are illustrated in Figure 3 c. The degree of hysteresis depends on the difference between the states of the system in the two regimes, and the amount the controlling variable needs to be reduced before the system can »flip« back to the alternate regime. Even if the perturbation is removed or reversed (e.g. by a reduction in nutrient load or reduced fishing pressure), the system may not return to its original state (Figure 3 d).

### BOX 8

#### ECOSYSTEM SHIFTS IN THE BALTIC SEA

The Baltic Sea has probably undergone several ecosystem shifts, for example, from a cod-rich, nutrient-poor and aerobic state to a cod-poor, eutrophicated and anaerobic state (Miljövårdsberedningen 2005, Österblom et al. 2007). The semi-enclosed brackish sea has more than 85 million people in nine different countries in its drainage basin. It is an important recreation area, supports a substantial fishery and constitutes an important route for transportation of oil and cargo, as well as being used for energy transport and production.

Water quality is negatively affected by poor sewage treatment in some countries and substantial run-off of nutrients originating from agriculture. Overfishing (including substantial illegal fishing) has resulted in dwindling stocks of important commercial fish species (e.g. cod).

Over the course of the last century, ecosystem state shifts have been identified with regards to eutrophication (in the 1950s) and due to a combination of changes in climate and overfishing (1989-1990). Changes in climate resulted in deteriorated conditions for cod and improved conditions for sprat. At the same time, fishing for cod was intensive, reducing the resilience of the stock to changing environmental conditions. We may stand at a threshold for an additional shift due to changes in climate during the coming decades, as all species in the Baltic Sea are sensitive to the delicate balance between salt- and fresh-water.

The drama, as shown in the collapse of the cod fisheries off the coast of Newfoundland that have not recovered despite a 17-year ban on fishing, is that systems crossing thresholds into new, undesirable states, tend to get stuck there, or are extremely difficult and expensive to reverse (MA 2005).

A »resilience lens« therefore puts emphasis on identifying alternate regimes and the capacity to avoid, or to change, the thresholds between them. Some of these system states are desirable from a human perspective and others are undesirable, depending on the flows of ecosystem services. And the same state may be deemed desirable and undesirable by different stakeholder groups. Persistence, adaptability and transformability determine a system's resilience and therefore the likelihood of state shifts.

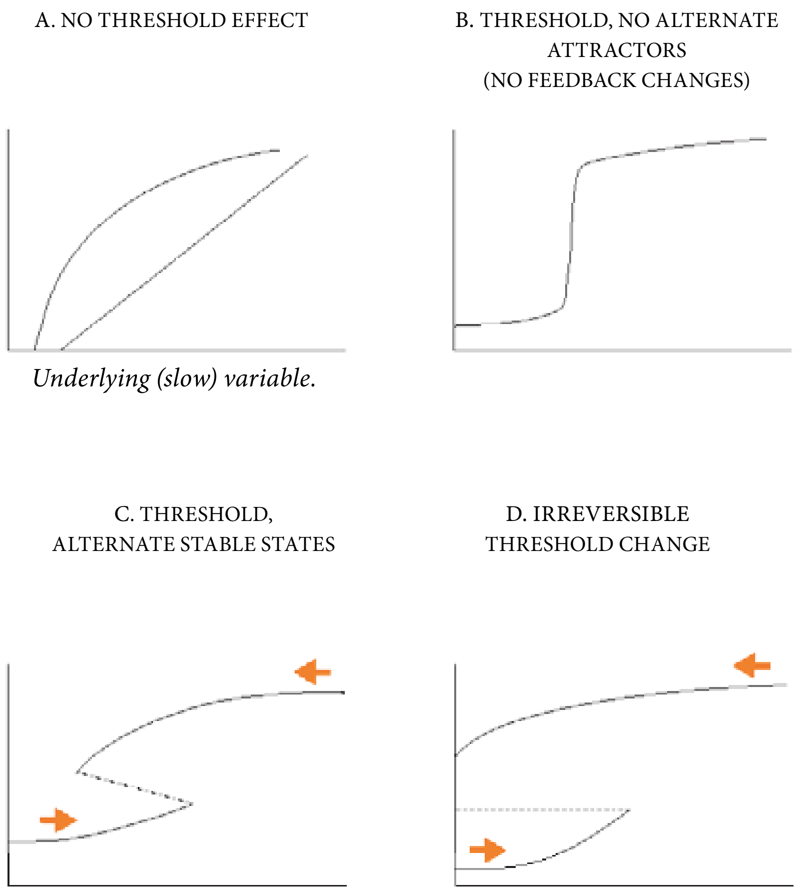



***Figure 3.*** *Illustration of the relationships between the state of a capital stock (or the abundance of a species, in the case of biodiversity) and the underlying variable that determines its dynamics. In (a) there is no discontinuity and the nature (and value) of the capital stock varies continuously with a change in the underlying (often slowly changing) variable. In (b) there is a very sharp (sometimes discontinuous) change in the capital stock, but it is reversible. In (c) there is a discontinuous change that is reversible but with a hysteretic return path, and in (d) the change is irreversible. The arrows indicate the direction of change in the underlying (slow) variable. (From Walker et al. 2009).*

## *Persistence*

Persistence (sometimes called »buffer capacity«) is one of the three key features of resilience (see Box 7). It is the capacity of a system to maintain structure and function when faced with disturbance (e.g. for a forest or coastal town to withstand the shock of a hurricane); in other words, to stay in the current regime. In this respect, resilience analysis is about understanding:

- Which state the system is in.
- How close to a threshold it is.
- How to navigate (either to avoid going into an undesirable regime or to get from an undesirable to a desirable one) and how to alter the resilience to make such navigation easier or more difficult.
- How exogenous drivers (e.g. rainfall, exchange rates) and endogenous processes (e.g. predator–prey cycles, management practices) lead to changes in the persistence of the current regime.

## *Adaptability*

Adaptability, the second key feature of resilience, is the capacity to manage resilience in order to stay within a desired system state (e.g. the ability to safeguard current food production systems under climate change), or to move from an undesired to a desirable state. It involves both the capacity to stay away from (or cross) thresholds, and the capacity to change the positions of thresholds (i.e. to increase or decrease resilience). This capacity to adapt is dynamic and is influenced by both natural and man-made capital, including: genetic diversity and response diversity (see 2.1), social networks and entitlements, human capital and institutions, governance, national income, health and technology.

Because human actions dominate in social-ecological systems, adaptability is mainly a function of the social component – the collective capacity of individuals and groups acting to manage the system. Their actions influence resilience, either intentionally or unintentionally. Their collective capacity to manage resilience, intentionally, will in many cases determine whether they can successfully avoid crossing into an undesirable regime, or cross back into a desirable one.

For the natural ecosystem itself, biodiversity is the general foundation upon which adaptability is built. Without genetic and species diversity, the options afforded natural selection are limited, and adaptation is virtually impossible.

### *Transformability*

Transformability, the third key feature of resilience, is the capacity to transform a social-ecological system into a different kind of system when ecological, economic, political and/or social conditions make continuation of the existing system untenable. It requires the capacity to learn and innovate, often during periods of crisis, but it also depends on having sufficient trust, leadership and available capital (social, natural and economic) before crisis ensues. It is strongly influenced by the state of the system at higher scales (the capacity, policy and attitude of a national government strongly influences the ability of a regional social-ecological system to transform itself). Transformation means introducing new components and new ways of making a living, and often a change in the scales that define the system. New variables can either be introduced or allowed to emerge. Examples could be turning the current financial crisis into an opportunity; transforming the global economy from one based on non-renewable resource consumption to an age of green economics (see Box 9), or shifting from large-scale industrial capture fisheries to smaller-scale coastal and recreational fisheries, as has been proposed for the over-exploited fish stocks of the Baltic Sea.

Transformation is about moving out of unsustainable situations by redefining the system in terms of what it consists of, the way it functions and the scales at which it functions. For many parts of the world the need now is actually to transform, not to make the existing system regime more resilient. The field of »transformation« and »transformability« is a research frontier of social-ecological systems.

Tensions may occur between maintaining the resilience of a desired current configuration in the face of known (and some unknown) shocks, and simultaneously building a capacity for transformability, should it be needed in the future. How can we foster or maintain the flexibility that will be required to cope with unforeseen challenges? Being a new field, little is known about the attributes required for transformability, but they will likely emphasise novelty, experimentation and learning as well as diversity and organisation in human capital (e.g. many different kinds of education, expertise and occupations). Moreover, trust, strengths and variety in institutions and speeds and types of cross-scale communication will likely be important. These all fall within the remit of adaptive governance; discussed in Chapter 3. Three capabilities determine whether successful transformation will occur: 1) preparedness to change (getting beyond the state of denial), 2) capacity to change and 3) options for change. Thus far, experience suggests that preparedness to change is a major hurdle.

There are many examples of social-ecological systems becoming trapped and unable to transform until it is too late (e.g. salinised agricultural systems; dams, floodplains and flood control; and forest fire suppression at ever larger scales). The question is: how might society develop the necessary transformability to avoid such lock-ins? In these situations building resilience is not the appropriate action. It would simply amount to »digging the hole deeper«. The question facing policy makers and planners will increasingly become: Which parts of our locality/region/country need enhanced resilience in order to ensure that their present states can continue, and which parts need to be transformed?


Photo: J.Lokrantz/azote.se

## BOX 9

### A POTENTIAL FOR TRANSFORMATION: TURNING THE CURRENT FINANCIAL CRISIS INTO AN OPPORTUNITY

Many now see the current financial crisis as an opportunity to transform the global economy. »We're now on the threshold of a global transformation – the age of green economics«, Ban Ki-Moon, the UN General Secretary, told Newsweek (October 25, 2008). Likewise, the new US president is planning to invest $15bn a year over the next decade in renewable energy and in creating five million new green jobs that »pay well, can't be outsourced and help end the US dependence on foreign oil«.

In conclusion, resilience is both a perspective – a way of thinking – as well as a measure. The »resilience lens« provides a framework for analysing social-ecological systems in a changing world facing many uncertainties and challenges. It is an area of explorative research under rapid development with major policy implications for sustainable development. It acknowledges that most of the unwelcome surprises in natural resource-use systems stem from a failure of the ruling management paradigm; a »command-and-control« approach underlain by four flawed assumptions regarding the behaviour and characteristics of these systems:

1. a focus on average conditions and particular time and space scales;
2. a belief that problems from different sectors in the systems do not interact;
3. an expectation that change will be incremental and linear, and
4. an assumption that keeping the system in some particular (»optimal«) state will maximise the flow of goods, indefinitely.

In contrast, governing resilience is concerned with learning how to avoid thresholds between alternate regimes, how to influence the positions of the thresholds and how to transform to a different kind of system when it is necessary. Managing complex social-ecological systems for resilience requires the ability to cope with, adapt to and shape change without losing options for future socio-economic development. When massive transformation occurs, resilient systems contain the experience and the diversity of options needed for renewal and redevelopment. In the current times of climate, financial and ecosystem-related crises, resilience is a concept that is increasingly being used in economic and development policies.

## 2.3. BIODIVERSITY, ECOSYSTEM SERVICES AND RESILIENCE

### *2.3.1. Biodiversity and Ecosystem Services*

The concept of ecosystem services is anthropocentric, emphasising the benefits that human societies gain from the functioning of ecosystems. The services we perceive as beneficial depend on a number of underlying natural processes, (decomposition, competition, predation, parasitism) provided by a myriad of organisms interacting with each other and the physical environment. Hence, all ecosystem services depend ultimately on the supporting services (biomass production, soil formation, nutrient cycling, water cycling, providing habitat), which in turn depend on the continued functioning of the different species in an ecosystem. Despite the uncertainties surrounding the mechanisms that link biodiversity to ecosystem processes and services, more species in an ecosystem – and especially more types of species with distinct functional attributes – tend to promote ecosystem processes such as biomass production, pollination, nutrient cycling and seed dispersal (EASAC 2009; see Box 10). Thus biodiversity is essential in the self-organising ability of ecosystems both in terms of absorbing disturbance and in regenerating and reorganising the system following disturbance (Folke et al. 2004).

In the early 1990s, insights from ecosystem ecologists started to emerge on aspects of biodiversity in ecosystem function (Schultze and Mooney 1993) and redundancy in ecosystem dynamics and development (Walker 1992). An ecological synthesis on the role of biodiversity in the functioning of ecosystems was developed by Holling et al. (1995), where they argued that only a small set of species and physical processes are essential in forming the structure and overall behaviour of ecosystems.

It is not the number of species per se, therefore, that helps sustain an ecosystem in a certain regime, but rather the existence of functional groups (see 2.1). Furthermore, species that may seem redundant for ecosystem functioning during certain stages of ecosystem development may become critical at other stages, under different conditions. They may, for example, become of critical importance for regenerating and reorganising the system after disturbance and disruption (Folke et al. 1996, Bellwood et al. 2004). This redundancy is found both between functional groups but also within functional groups. As such, this apparent »redundancy« actually constitutes the ecosystem's response diversity (see 2.1.). Loss of response diversity means that disturbances that were buffered and that may have helped revitalise a system before diversity loss can instead spark practically irreversible shifts in the system (Folke et al. 2004).

### BOX 10

### THE ROLE OF FUNCTIONAL DIVERSITY IN POLLINATION

In an experiment 80km south-west of Paris, Fontaine et al. (2005) found that experimental increases of the functional diversity of both plants and pollinators led to a recruitment of more diverse plant communities. The experiment was composed of 36 plant communities with different combinations of local pollinators (flies, bees and both insects) released into nylon-mesh enclosures.

Two years after the experiment, plant communities pollinated by the most functionally diverse pollinator assemblage contained about 50% more plant species than plant communities pollinated by less-diverse pollinator assemblages. The positive effect on plant diversity was explained by a combined effect from functional groups of both plants and pollinators. The conclusion was that functional diversity of pollination networks is important for ecosystem sustainability.

Other studies question if the well-established relationship between biological and functional diversity will hold for realistic scenarios of extinctions or at larger spatial scales than reported in most small-scale case studies (Srivastava and Vellend 2005).

## *2.3.2. The Role of Biodiversity in the Resilience of Ecosystem Services*

As described above, levels of response diversity to environmental change within functional groups are critical to ecosystem resilience (see also Chapin et al. 1997, Elmqvist et al. 2003) and Box 11 provides an example of loss of resilience through low species diversity.

Biodiversity enhances the resilience of desirable ecosystem states because different species respond differently to a disturbance, enabling the ecosystem to continue performing all critical processes (see also 2.1 and Box 12). Low functional diversity leads to a fragile ecosystem (see Naeem 2002 for a review); a system with a single species supporting an important ecological function is less resilient than a system where several species support the same function. Response diversity expands the concept of functional diversity and clearly emphasises that it is crucial to also consider the different responses to environmental change and disturbances among species contributing to the same


BOX 11

### THE PATHOLOGY OF MONOCULTURES: THE CASE OF THE STORM GUDRUN AND THE SUDDEN LOSS OF 50 YEARS OF FOREST INVESTMENT

In January 2005, the storm Gudrun swept through Sweden, blowing down 70 million cubic metres of wood – roughly one year's harvest in the country. Record damages over the past 30 years were observed in Sweden, but Latvia, Denmark, Estonia and Lithuania also experienced significant forest damages.

Decades of monoculture-oriented forest policy had led to a loss of resilience to storms, resulting in severe consequences. The trigger was a freak storm occurring under warm and moist conditions.

The impacted forests were monoculture stands of spruce, Sweden's most vulnerable tree species to windthrow, with a large and dense crown and a modest and comparatively shallow root system. Moreover, the mild weather and rain in December and January had severely weakened the hold of the roots. Apart from the low diversity of trees and the warm and moist conditions other factors also contributed to the magnitude of Gudrun's adverse effect (e.g. the prevailing thinning and cutting regimes)(Haanpää et al 2006).

ecosystem function. That is, if all species within a functional group would be equally sensitive to a particular disturbance then the system would have a low response diversity and be very vulnerable, despite having a high functional diversity. This is particularly pertinent in the context of large-scale driving forces such as climate change. Box 12 illustrates the complexity of the dynamics involved. In this example it is the combination of the interaction between two organisms that can alter the system's productivity and response to climate changes.

### *2.3.3. Resilience of Ecosystem Services in Social-Ecological Systems*

The challenge facing the EU, and the world, is to sustain the capacity of ecosystems to generate valuable ecosystem services. Achieving this requires enhancing the resilience of the social-ecological systems concerned.

Management can diminish or build resilience. There are many examples where management has altered slow-changing ecological variables, such as soil

#### BOX 12

#### THE ROLE OF MYCORRHIZA IN THE PREVENTION OF DESERTIFICATION – A CASE STUDY FROM THE MEDITERRANEAN

Fungi and vascular plants cooperate in a symbiotic association called mycorrhiza, where fungi colonise plant roots. This association provides the fungi with carbohydrates produced by the plant. In return, the plant gains the use of the very large surface area in the fungi mycelium to absorb water and mineral nutrients from the soil. The positive effects of mycohrriza have been shown in numerous studies (e.g. Malloch et al. 1980); plants growing without mycorrhiza perform poorly and have significantly reduced competitive abilities.

One example of the positive effects of this relationship comes from semi-arid shrublands in the Mediterranean basin. Large areas of the native shrubland in this region are degraded due to erosion and desertification. There are several ongoing restoration projects aiming to restore native biodiversity and prevent further degradation. Field experiments (e.g. Azcón-Aguilar et al. 2003, Caravaca et al. 2003) have shown that plantation of native shrub species on degraded semi-arid land is far more successful if plants are inoculated with arbuscular mycorrhizal (AM) fungi or an allochthonous AM fungus.

It is concluded that the role of AM fungi in semi-arid Mediterranean shrublands is a key element in determining the survival, establishment and functioning of the vegetation in this sensitive region, currently undergoing rapid changes related to climate change.


chemistry, organic matter or biodiversity, with disastrous consequences that did not appear until long after the ecosystems had been critically affected; time-lags between cause and effect. Similarly, management can disrupt flexible social institutions and experiences or remove mechanisms for creative and adaptive responses by people. Erosion of these sources of resilience can have consequences not only on the natural resource base, but also for human livelihoods, vulnerability, security and conflicts. Resilience depends not only on ecological factors such as biodiversity, but also on social factors.


Photo: J. Eklöf/azote.se

# Governance of Biodiversity in a Future Dominated by Climate Change & Other Global Change Impacts

CHAPTER 3

## 3.1 INTRODUCTION

Governance is a process involving the interactions of diverse public and private actors, their sometimes conflicting objectives and the instruments chosen to steer social and environmental processes within a particular policy area (Stoker 1998, Pierre 1999, Jordan et al. 2005, Pierre and Peters 2005). Herein institutions are the »humanly devised constraints that shape human interaction« (North 1990), the rules and norms that constrain natural resource use, while organisations or bodies develop and enforce these. Carter (2007) suggests that environmental policy issues in general pose challenges to conventional modes of governance since they are often trans-boundary, complex, working across levels as well as different time scales and because they relate to public goods and common-pool resources; all relevant to biodiversity issues.

The »Rio-model« of global environmental governance (initiated at UNCED, Rio de Janeiro, 1992) was based upon a focus on trans-boundary environmental problems as a challenge to the state, with a correlate emphasis on international governance bodies as the major measure to approach environmental problems. According to Conca (2005) there were three flaws in this analysis. The first has to do with the fact that many environmental problems are locally embedded but accumulate at the global level, such as deforestation and the emission of greenhouse gases by local industries. Second, there was an assumption that states, even when faced with trans-boundary problems, were the authoritative actors within their territories. Third, there was a tendency to think of ecological globalisation as progressing more rapidly than economic or social globalisation, which entailed insufficient attention to the challenge of how to govern the effects of globalisation. An example relates to the global capacity of some actors to extract resources, the complexity of commodity chains and the extent that some environmental problems are »outsourced« to developing countries (see Box 13).

The challenge facing global environmental governance mirrors the recognition in policy science that there has been a shift from government to governance in society's management of social problems (Pierre and Peters 2005). In general terms, this implies a shift from the state as the primary holder of authority (steering through a bureaucratic system that uses regulative policy instruments and relies on an administrative rationale) to a situation where several groups of actors may claim authority. In this new situation, networks have emerged as an important governance form besides hierarchy, and communicative and market policy instruments are increasingly used, including various forms of public-private partnerships. Whereas the administrative rationale of government favours predictability and equality before the law, governance gives preference to values like flexibility, adaptability, participation, effectiveness and efficiency. The state has, however, not lost its importance in governance, but its role is sometimes more of an initiator and facilitator of policy development than a traditional regulator.

The shift from government to governance raises a number of important questions regarding what makes a policy legitimate and how accountability can be secured in a context where no single actor bears responsibility. Another trend is that the more the complexity of the issues increases, the more conventional, substantive sources of legitimacy (e.g. legality of the sovereign state) are challenged. No wonder then that the governance debate in relation to environmental problems has come to converge around issues of legitimacy, effectiveness and accountability. There is also an increased interest in policy and academic circles, for stakeholder participation, dialogue, platforms for conflict mitigation and learning in environmental policy-making and implementation. Here, we refer to this implementation process as »adaptive co-management«. Adaptive co-management refers to the multilevel and cross-organisational management of ecosystems (Gadgil et al. 2000, Wollenberg et al. 2000, Ruitenbeek and Cartier 2001, Folke et al. 2005). This management underlines the need for a flexible approach and embraces the

### BOX 13
### GLOBALISATION AND ITS EFFECTS ON MARINE RESOURCES

Berkes and colleagues (2006) illustrate how highly mobile actors are capable of harvesting marine resources from around the world and bringing them to globalised markets that have developed faster than the capacity of institutions to respond to this resource extraction. These highly mobile »roving bandits« have sequentially exploited and overharvested species in regions with inadequate legal frameworks and institutional capacity. The study illustrates spatial (locally-rooted institutions versus highly mobile fleets), temporal (relatively fast rates of ecological and market-driven change versus slow evolution of international and local institutions) and probable threshold misfits (risk of collapse due to inadequate institutional response). Many species and habitats previously too inaccessible to be economically viable targets for fishers are now open to exploitation.

In another study, Deutsch and colleagues (2007) illustrate some of the global implications of European seafood consumption of aquaculture-produced salmon and tiger prawns. In the case of shrimp farming, which has expanded tremendously during the last decades, ponds are established in coastal areas of tropical countries. This expansion of farms not only leads to destruction of coastal mangrove forests and the biodiversity they host, but also entails threats to human health from antibiotics and pesticides, a rise of sea-polluting waste effluents and the depletion of wild fish stocks due to habitat loss (Burke et al. 2001, UNEP 2006). Moreover, shrimp farming requires fishmeal. Deutsch and colleagues (2007) mapped the import of fishmeal to Thailand, the world leader in tiger prawn production, between 1980 and 2000. Originally an exporter of fishmeal, Thailand now imports fishmeal from all the corners of the world.

In this way, Thai shrimp farming uses the capacity of the main part of the Earth's productive marine ecosystems for the production of shrimps in ponds. These shrimp are to a large extent exported and may end up on the plate of a customer in a sushi restaurant in Brussels. Such trade flows are tightly linked with ecosystem productivity and resilience, though very little biological/ ecological information on these flows are available (e.g. species composition in traded fishmeal and fish stock status), and clearly illustrate some of the outsourcing of environmental impacts that result from unregulated globalisation.

importance of stakeholder dialogue and participation.

From a critical perspective, the focus on governance risks losing sight of the cases where a core problem is that the state lacks legitimate control. It can be argued that the governance literature is also promoting an idea of a specific mode of governing in line with the liberal state that will only prolong its contri-

## BOX 14

### HOW EFFECTIVE IS ADAPTIVE CO-MANAGEMENT? EXAMPLES FROM 146 UNESCO BIOSPHERE RESERVES AROUND THE WORLD

Schultz et al. (2009) conducted a global survey to test the effects of participation and adaptive co-management in the World Network of UNESCO Biosphere Reserves. Analysing survey-responses from 146 Biosphere Reserves in 55 countries the study found that adaptive co-management was associated with higher levels of self-evaluated effectiveness in achieving development goals, but not at the expense of biodiversity conservation. Local participation seemed to enhance support by local inhabitants, improve integration of conservation and development and have a positive effect on fostering sustainable development. The results of the survey also indicated that participation of scientists increases the effectiveness in achieving »conventional« conservation goals and that policy-makers enhance the integration of conservation and development into other policy areas.

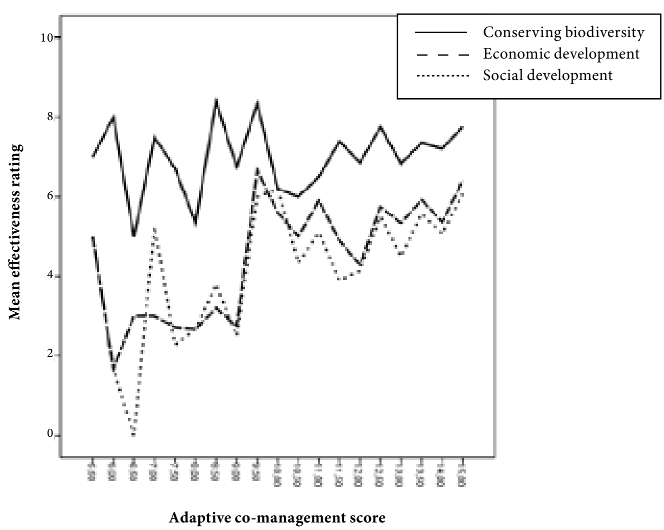



**Figure 4.** Average effectiveness ratings (for biodiversity conservation, economic- and social development) and adaptive co-management scores (Schultz et al. 2009).

bution to environmental degradation. Despite these concerns, a growing recognition exists of the potential in the adaptive co-management perspective when addressing dynamic social-ecological systems (see Box 14), and this perspective will be the focus for this chapter.

### *3.1.1. The Political Context of the CBD and the MDGs*

The states party to the Convention on Biological Diversity (CBD) committed themselves (in 2002) to improve implementation of the CBD and to »achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national levels as a contribution to poverty alleviation and to the benefit of all life on Earth«. This mission was inspired by the decision taken by the European Council in Gothenburg 2001 to »halt biodiversity decline with the aim to reach this objective by 2010«. The CBD target was subsequently endorsed by the World Summit on Sustainable Development in Johannesburg in 2002 as well as the United Nations General Assembly and incorporated as a target under the Millennium Development Goals (see Table 3). Parties of the CBD are also committed to meeting the global biodiversity challenges by building adequate capacity for implementation, for developing national actions to conserve and maintain biodiversity, as well as, for integrating biodiversity concerns in economic sectors and in improving the awareness in society of the importance of biodiversity. These actions are perceived as being of particular strategic importance to improve implementation of the Convention. This chapter focuses on the first two commitments (the third is well addressed by TEEB 2008), the fourth commitment is raised in the text but not discussed in depth; this needs to be addressed to better allow bottom-up initiatives as well as for increasing legitimacy of decisions.

The UN Millennium Development Goals (MDGs) were established to improve human well-being on the planet by 2015 (see Table 3). The MDGs of halving hunger, poverty and health threats are already at risk due to climate change, which is impacting society globally. The poor and most vulnerable are worst hit, and are expected to bear the largest burden of a climate crisis they have not caused (IPCC 2007). Many of these impacts can be directly linked to loss of biodiversity and associated ecosystem services, which most likely have both direct and indirect negative impacts on several of the MDGs. In 2008, biodiversity was included as part of the MDGs, which further moved bio-


Photo: R. Kautsky/azote.se

| *Table 3.* THE 2001 UN MILLENNIUM DEVELOPMENT GOALS INCLUDING THE NEW TARGET 7B ESTABLISHED IN 2008 |
|---|
| *1. Eradicate extreme poverty and hunger* |
| *2. Achieve universal primary education* |
| *3. Promote gender equity and empower women* |
| *4. Reduce child mortality* |
| *5. Improve maternal health* |
| *6. Combat major diseases* |
| *7. Ensure environmental sustainability*<br>*7b. To reduce biodiversity loss, achieving, by2010, a significant reduction in the rate of loss* |
| *8. Develop a global partnership* |

| INDICATORS FOR MONITORING PROGRESS OF GOAL 7 |
|---|
| *7.1 Proportion of land area covered by forest* |
| *7.2 $CO_2$ emissions, total, per capita and per $1 GDP* |
| *7.3 Consumption of ozone-depleting substances* |
| *7.4 Proportion of fish stocks within safe biological limits* |
| *7.5 Proportion of total water resources used* |
| *7.6 Proportion of terrestrial and marine areas protected* |
| *7.7 Proportion of species threatened with extinction* |

diversity onto the political agenda. This was an important step in changing the perception from mankind as independent of ecosystems, or the environment, to a worldview where human and ecological systems are perceived as truly interdependent and constantly co-evolving.

### *3.1.2. A Piecemeal Approach to Protecting Biodiversity*

The increased political attention at global, European, national and local levels of the need for protecting biodiversity and ecosystem services has indeed had a range of positive effects, but mainly in a piecemeal fashion and primarily at local/regional levels; often in the form of protected areas or species-specific actions. One notable exception is the European ecological network of protected areas, Natura 2000, consisting of the Birds Directive (requiring the establishment of Special Protection Areas for birds) and the Habitats Directive (requiring Special Areas of Conservation designed for other species and for habitats).

Substantial changes of biodiversity governance and management systems at the landscape level are, however, rare, and have, with few exceptions, only come as a result of serious depletion of the natural resource base, i.e. a response to a situation when critical and potentially irreversible thresholds have already been passed in ecosystems (see section 2.2 for a more in-depth analysis of non-linear effects). Why do governance systems continually fail to be proactive and protect vital ecosystem functions and resources? Important external factors can include a lack of alternative livelihoods, corruption, administrative fragmentation and inefficiency or misdirected incentives. A fundamental but seldom elaborated internal factor in institutional failure, however, appears to be a general lack of acknowledgment by decision-makers of the dynamics of strongly interconnected social-ecological systems.

### *3.1.3. Governance of Social-Ecological Systems*

Social-ecological systems are not just social and ecological systems, with some temporal and weak links in between (Westley et al. 2002). This conventional understanding that sees the socio-economic system only as extracting natural resources from the ecological system, which in turn receives disturbances (such as pollution, over-exploitation of species and resource extraction) from the socio-economic system has proven to be overly simplistic. Human society may show a great ability to design institutions, mobilise collective action and respond to changing circumstances, but the institutional and other societal responses may occur at the expense of changes in the long-term capacity of ecosystems to generate ecosystem services to human societies if insufficient attention is paid to, or knowledge exists of, the ecological system in question (Huitric 2005). Likewise, designing institutions on ecological knowledge alone, without recognising the fundamental impact of other institutions and social actors on ecological systems, fails to appreciate the complexity of governance processes, mental models (Adams et al. 2003) and the social features that enable management of dynamic ecosystems (Folke et al. 2005), and is bound to fail. A number of syntheses point to the strong feedback and co-evolution between social and ecological systems (Berkes and Folke 1998, Steffen et al. 2004). Liu and colleagues (2007), for example, elaborate how ecological change and decision making alternate in periods of time, creating reciprocal interactions between human and natural systems (see also Costanza et al. 2005).

Current levels of biological diversity are shaped by, or even the result of, human actions in landscapes and seascapes (Scheffer et al. 2001, Halpern et al. 2008). In this context, it is becoming increasingly clear that we can no longer focus solely on the protection of genetically distinct organisms and megadiversity hot spots. Instead, we need to complement this with new kinds of governance and management systems aiming to restore, support and enhance ecosystems' capacity to generate ecosystem services (Carpenter et al. 2009; see section 3.2.4), clearly a much more difficult task. Doing this is as much a social endeavour as it is an ecological endeavour, and as much about managing relationships among different stakeholders as it is about managing ecosystems (Natcher et al. 2005, Stenseke 2009). This new type of governance must put emphasis on navigating and enabling the generation of ecosystem services rather than managing and controlling because ecosystems are moving targets subject to complex dynamics (Levin 1999). Social systems and the human-induced driving forces on ecosystems may be equally dynamic (Ostrom 2005). The challenge for governance and management of biodiversity is to nurture resilience in the social-ecological systems they are embedded in (Chapin et al. 2009, Schultz et al. 2009). In this context, successful management of biodiversity and ecosystem services requires adaptive governance systems characterised by continuous generation of ecological understanding and learning environments that accept uncertainty and adjust their response capacity to deal with change (Berkes et al. 2003, Ostrom 2007).

## 3.2. CAN CRITICAL COMPONENTS OF ADAPTIVE GOVERNANCE BE IDENTIFIED?

Governance of biodiversity and ecosystem services aims to steer dynamic social-ecological systems towards more resilient and productive states and to avoid disasters or undesired regime shifts. Naturally, should the latter occur then governance is the process of figuring out how to restore or transform the system. The notion of »adaptive governance« discussed by Dietz et al. (2003) and Folke et al. (2005) conveys the difficulty of control, the need to proceed in the face of substantial uncertainty and the importance of dealing with diversity and reconciling conflict among people and groups who differ in values, interests, perspectives, power and the kinds of information they bring to situations.

This approach also recognises the need both to govern the social and ecological components of social-ecological systems as well as to build a capacity to harness exogenous institutional and ecological drivers that might pose possibilities or challenges to social actors (Dietz et al. 2003, Folke et al. 2005); pertinent to the environmental problem characteristics listed in 3.1. Folke and colleagues (2005) highlight the following four interacting aspects to be of importance in adaptive governance of social-ecological systems:

1. Build knowledge of ecosystem dynamics.
2. Feed knowledge into adaptive management to create conditions for learning.
3. Support flexible institutions and multi-level governance systems.
4. Deal with the unpredictable.

### *3.2.1. Build Knowledge of Ecosystem Dynamics*

Incomplete knowledge and understanding of ecosystem and social-ecological system functioning remains a key problem. Science, collaborative research and local knowledge systems, as well as scientifically sound monitoring are important components for building knowledge. Successful adaptive governance of biodiversity and ecosystem services requires substantial and legitimate knowledge at all geographical levels (see Box 15). The Millennium Ecosystem Assessment, and other recent global-level assessments, have proven to provide valid pedagogic instruments to inform policymakers that the degradation of ecosystems has negative impacts on human well-being, and that an ecosystem service approach is a good tool for integrating environment and poverty issues, including the many aspects of climate change (Wells et al. 2006, House of Commons, Environmental Audit Committee 2007).

Moreover, the driving forces behind the loss of diversity at all levels are interlinked with virtually all human activities under economic sectors in society, meaning that assessing what are efficient measures in order to achieve a specific outcome becomes very complex (see Box 16). For example, is a recent increase in cod stocks in the Baltic Sea a result of favourable climatic conditions or reduced fishing pressure or both? How does seal predation and eutrophication influence the dynamics of the cod stock? Should management measures aimed at increasing the cod stock be targeted at long-term mitigation of climate change, medium-term reduction of nutrients, short-term reduction of fishing pressure, or all of the above? Which measures are efficient and motivated? Without knowledge of ecosystem dynamics, there is a real risk of prioritising sub-optimal measures, such as 1) scale-deficient measures (e.g. single species or area protection as opposed to an ecosystem approach), 2) timescale-deficient measures (e.g. poor adaptability to long-term system changes) or 3) system-perverse measures (e.g. substituting petroleum with ethanol produced from food crops that has negative environmental and biodiversity impacts, and exporting overcapacity of fishing fleets to developing nations).

## BOX 15

### SYNTHESISING KNOWLEDGE AND QUANTIFYING TARGETS

There seems to be a move in a number of European policy areas towards defining and quantifying desired targets of ecosystem status. The Water Framework Directive (2000/60/EC) specifies that (geographically specific) »Good ecological status« and »Good chemical status« should be defined and then managed towards. Quantifying these statuses is a difficult task and assumes that there is some stable domain of the ecosystem that can be achieved. This approach puts priority on the ecological conditions (although it may be argued that this approach also understates the uncertainties and system complexities) and requires significant discussion with stakeholders to ensure legitimacy of the quantified targets as well as identifying means of reaching the defined targets. In the Baltic Sea, there has also been a shift to quantifying the »desired state«.

The Baltic Sea Action Plan (HELCOM 2007) included science-based measures to reduce eutrophication in order to improve water quality back to its status in the 1950s. The definitions of needed nutrient reductions were preceded by a decade of data collection and modelling and the creation of a tool for scenarios of different nutrient run-off trajectories and their impacts on the desired ecosystem service (water quality). Using the NEST decision support system, it was possible to describe the nutrient loads needed (and hence reductions required) in order to reach the desired environmental status (as defined by HELCOM experts). The decision support system could also be used to develop an allocation scheme for needed actions that was perceived as fair by all governments. The nutrient reductions required in the BSAP included very substantial actions. National and international monitoring programs are closely following the effects of reduction measures taken, the flow of nutrients in the drainage basin and the impact on water quality from the reduced nutrient loads. This method of using a decision support system required substantial international collaboration among scientists and shares many similarities with the European work on air pollutants, using the Regional Air Pollution Information and Simulation (RAINS) model. This model was an important tool for creating scientific consensus and defining »critical loads« of air pollutants, which contributed to the formulation of the Convention on Long Range Trans-boundary Air Pollutants (LRTAP).

Somewhat analogous »sharp« targets were formulated for the protection of the Australian Great Barrier Reef: The extent of its protected area was to be increased from 5 to 30 % in order to preserve ecosystem resilience. This dramatic measure was possible to implement with a high degree of legitimacy thanks to very substantial stakeholder consultations and a willingness to make compromises (Hughes et al. 2007, Olsson et al. 2008).


*Photo: C. Clifstock*

## BOX 16
### TOWORDS KNOWLEDGE-BASED MANAGEMENT OF EUROPEAN SEAS

The EU Marine Strategy Framework Directive (2008/56/EC) takes a holistic approach in addressing human activities impacting the marine environment. The directive is unique in its strong focus on maintaining biodiversity and sustaining clean, healthy and productive seas. The focus of the directive is on the sustainable use of goods and services, with a special emphasis on resilience. It is also unique as it ambitiously tries to integrate concerns from other policy areas. Its overarching framework binds Member States to action and there is a firm timetable, but implementation is regional, using existing bodies of governance. Additional key aspects are that the starting point is the ecosystem and that spatial protection measures (e.g. marine protected areas as part of a wider scheme of marine spatial planning) are underlined. All this renders the directive very »knowledge-intensive«, requiring region-specific programs of measures including assessments of pressures and impacts on the ecosystem, as well as economic and social analyses of resource use and of the cost of degradation of the marine environment. The aim is to accomplish a defined »good« environmental status. If the obvious difficulties in defining such a status in dynamic ecosystems can be overcome, then the directive has the potential to be a leading policy instrument for integrating resilience in European natural resource management.

## *Combining Different Types of Knowledge for Learning*

In light of current and predicted changes in status of biodiversity, we will need to use all knowledge sources available. Because of the complexity involved, one or a few people, or organisation(s) rarely possess the range of knowledge (and capacity) needed for effective ecosystem management (Berkes 2002, Brown 2003, Gadgil et al. 2003, Olsson et al. 2004). Scientific bodies, including governmental administrations, are relatively well-organised and are producing good and crucial information. The knowledge needed for good governance, however, is not always contained in this formal system. Knowledge is built up and applied through monitoring, interpreting and responding to ecosystem feedback at multiple scales by a wide array of actors (Folke et al. 2005). Consequently, it is necessary to also include: local, traditional and indigenous knowledge (see Box 17).

Knowledge is thus dispersed among a diversity of individuals and organisations and needs to be mobilised to become of practical use in management (Imperial 1999, Olsson et al. 2006). Such mobilisation of different knowledge systems can take place in a »social learning« process (Lee 1993), meaning »learning that occurs when people engage with one another, sharing diverse perspectives and experiences to develop a common framework of understanding and basis for joint action« (Schusler et al. 2003). In this way social learning integrates issues of knowledge generation, working out objectives, solving conflicts and action. Both mobilisation of knowledge and learning require interacting social networks (Imperial 1999, Olsson et al. 2006). To achieve sufficient fit between a biophysical system and rights, rules and decision-making, procedures need to be premised on these kinds of knowledge-sharing and knowledge-generative processes (see section 3.2.2).

This diversity of knowledge systems implies that management systems unknown to, or unrecognised by, the EU/ governments exist for many resources (e.g. see Box 18). Many high-level decisions and rules over-ride well-established resource management systems, incurring not only a breakdown in management of the resource but also loss of knowledge as the new system is not structured to incorporate this knowledge, and can result in conflict. Instead, governance needs to create institutions that support and bring together existing knowledge. Achieving an overview of existing actors and knowledge


## BOX 17
## COLLABORATIVE RESEARCH USING FISHERS' KNOWLEDGE AND INFRASTRUCTURE

The local knowledge of fishermen has proven to be an important complement to traditional fisheries science in a range of settings, a fact that is hardly surprising given the relative difference in sample size between daily fishing trips and annual research cruises. For example, the inclusion of fisherman knowledge is conducted in a systematic manner in regional management councils in both the US and Canada. These collaborative research projects include both researchers and fishermen and have proven to be an efficient way to use resources and successfully build trust and increase mutual understanding between industry and scientists. The projects in the US are commonly initiated jointly by science and industry, are evaluated and ranked by research steering committees and compete for federal funding. These collaborations have in some instances led to dramatic change in how the status of some fish stocks (e.g. monkfish) is assessed (Haring and Maguire 2008, personal communication P. Haring).

Participation of fishermen in research can be high: 30-50 % of the fishermen active within the jurisdiction of the New England Fishery Management Council in the US are taking part in these research programs. Similarly, a major part of the research conducted by the Norwegian Institute for Marine Research (currently one third of the at-sea research days) is conducted with the use of hired commercial fishing vessels. Collaborative research between fishers and scientists has been shown to allow the exchange of skills and knowledge between these groups, to create greater legitimacy of the scientific advice and to contribute to addressing differences in knowledge and perceptions, i.e. it is starting to break down traditional barriers, creating room for a constructive dialogue (Hoefnagel et al. 2006, Stanley and Rice 2007). The use of fishing vessels for monitoring and research also provides an additional source of income for fishing fleets and coastal communities (McCay et al. 2006). Adapted from Baltic Sea 2020 (2009)


## BOX 18

### DISPUTE SETTLEMENT IN SPANISH WATER COURTS

Every Thursday at noon, the Tribunal de las Aguas de Valencia (the Water Court of Valencia), which has existed since the 15th century, meets in front of the Cathedral of Valencia (see photo above), to settle disputes related to water resources. These disputes are related to the use and function of the acequias, a community-operated waterway (engineered canals that carry river water to agricultural fields). The most frequent cases heard by the court involve farmers and are related to issues of damages in the infrastructure, compliance with water allocation turns, or changes on the water allocation regime. The Tribunal has also been called on to resolve disputes between non-farmers, including the City council and real-estate promoters. A process by which the tribunal can visit the field to observe the facts of the case often precedes the meetings. The time period between the day the complaint is made and that when the jury meet to hear the defendant and dictate sentence should not take more than a week.

During a period when the city grew exponentially, the Tribunal de las Aguas was commonly used by irrigators and real-estate promoters as a quicker and less costly alternative than ordinary courts to accommodate urban developers' actions and irrigators' rights. The meetings of the jury have recently become a tourist attraction, which has contributed to a decreasing number of cases heard (in order to avoid the public exposition that the hearings involve). The decrease in number of cases reviewed, however, has not undermined the Tribunal's legitimacy or authority; indeed, compliance with the Tribunal's sentences, both by members and non-members of the concerned acequias is very high (Based on research by S. Villamayor-Tomas. Sources: Iglesias Kuntz 2006, Pizarro Náñez 2008, Conversations with representative of Acequia de Mestalla and with secretary of the Tribunal de las Aguas de Valencia 2009).

systems has been referred to as »social-ecological inventories« (Schultz et al. 2007). Traditional inventories of biodiversity need also account for the management practices that sustain or degrade biological diversity and the generation of ecosystem services, i.e. understanding what people are doing on the ground in relation to biodiversity and ecosystem services.

### *3.2.2. Feed Knowledge into Adaptive Management to Create Conditions for Learning*

To ensure adaptive management, it is important to plan for and continuously assess and follow up programs and adapt management according to the actual state of the resource/environment.

The ecological knowledge generated at different scales is important for an adaptive management approach, where governance structures can then test different solutions, innovate and learn. Adaptive co-management addresses the complexity and inter-connectedness of social-ecological systems by emphasising a learning-by-doing approach through continuous monitoring and adapting responses to feedback from the ecosystem in collaboration with a diversity of stakeholders (Holling 1978, Olsson et al. 2004; see Box 19). This requires governance systems that allow for and support »ecosystem stewardship« – a stewardship of ecosystems for human well-being in a world dominated by uncertainty and change (Chapin et al. 2009). In this way learning is tightly coupled with application of management.


## BOX 19
## CREATING LEARNING ARENAS FOR ADAPTIVE CO-MANAGEMENT: TESTING THE WATERS

The Grand Canyon is one of the largest geomorphic features on the planet, created over the past 6–10 million years by the Colorado River, and is almost 500 km in length. The completion of the Glen Canyon dam in 1962 altered the hydrological regime of the middle Colorado River in order to control annual variability in water flow and to generate electricity. The river was historically characterised by extreme floods, large sediment loads and seasonally large temperature fluctuations. Today, for hundreds of kilometres downstream of the dam, the river has a relatively stable flow, clearer water and a near-constant temperature. These physical changes have led to ecosystem shifts, such as the loss of seven species of native fish, the endangerment of another four and a reduction of habitat diversity.

Ecosystem management in the canyon has focused on attempting to return the system to more desirable ecological regimes. Key objectives include better protection for a suite of native fish that are currently vulnerable to extinction, restoration of sediment input and return of a seasonal temperature regime. These objectives have been pursued through an ambitious management program that has conducted two experimental releases of large volumes of water from the dam, in 1996 and 2004. These experimental releases allowed scientists to develop a better understanding of sediment dynamics and how water temperature and introduced pests (salmonid predators) influence the recruitment dynamics of an endangered native fish, the humpback chub.

A new body was developed in 1997, the Grand Canyon Adaptive Management Work Group, which uses planned management actions and monitoring to test hypotheses and build understanding of ecosystem dynamics. Local community leaders understand the uncertainties and complexities of the system and believe that resolution of environmental issues can only be discovered and not determined by predetermined policy. This view has provided vital opportunities for experimentation and learning. This approach has generated a great deal of trust among stakeholders and provides a flexible institutional setting for dealing with multiple objectives. (Adapted from Hughes et al. 2007)

## *Learning and Social Networks*

Westley (2002) argues that the capacity to deal with the interactive dynamics of social and ecological systems requires learning environments and social networks of interacting individuals and organisations at different levels to create the right links, at the right time, around the right issues. There are a number of scientific papers that offer an overview and explore typologies of learning and various avenues for learning in collaborative environmental management (e.g. Garaway and Arthur 2004, Cook et al. 2004, Fazey et al. 2005, Armitage et al. 2008). The adaptive governance approach used in the Kristianstads Vattenrike Biosphere Reserve in Sweden (see Box 22) relies on a social network of multiple actors and actor groups of which a »bridging organisation« is the key node (Hahn et al. 2006, Olsson et al. 2007; bridging organisations are discussed in more detail in section 3.2.3.). The organisation plays a central role in creating a learning platform (places or occasions, real or virtual, where people meet to learn from each other's experiences of a resource or ecosystem, e.g. advisory boards and community forums), by eliciting common goals, creating an atmosphere of trust, brokering organisational and individual contributions and deploying energies in accordance with some strategic plan.

Failure to address both the ecological and social contexts will always result in an environmental or resource regime misfit (as seen in section 3.1.3.); that institutions are set at too large or small time- or space-scales, or address an insufficient number of ecosystem (or social) variables in their efforts to deliver efficiency, reliability and optimality of ecosystem goods and services (Holling and Meffe 1996). These factors are important to take into account when planning for, and conducting, adaptive co-management

Likewise, blueprint, command-and-control approaches for managing natural resources often fail to match the diversity of different local settings and the complexity of people and ecosystems (Holling and Meffe 1996, Wilson 2006). As a consequence, this management approach has pushed many social-ecological systems into degraded states (Scheffer et al. 2001, Folke et al. 2004). Instead, case-specific (to allow good fit) and adaptive (to maintain fit under changing conditions) approaches are needed. This does not mean lifting all responsibility or input from higher hierarchical levels. There is a definite role for large-scale government and non-governmental organisations related to compiling information provided by smaller units, overseeing progress (or lack of progress) at lower levels, helping to resolve conflicts and taking corrective actions related to processes whose primary effects are at the larger scale.

### *3.2.3. Support Flexible Institutions and Mutilevel Governance Systems*

Flexible institutions are rules that adapt to new information and that allow for local diversity. This means that there is mechanism or space for updating rules and that these rules can be applied differently in different places (adapting to local and changing contexts). They should allow for adaptive co-management by allowing detection and response to changes by mobilising resources, know-how and support for action. In order to be flexible, these institutions require input from a mix of scientists, formal managing bodies and other stakeholders and links between horizontal (sectors) and vertical (hierarchies) scales. It is important to take time to meet and develop joint hypotheses about how the »system« works, and which management actions are likely to generate results, thereby stimulating trust-building between stakeholders.

Natural resource users trying to preserve biodiversity and ecosystem services tend to find themselves facing not only potential collective-action problems with other users (Ostrom 1990) but also a plethora of interlinked local, national and international institutions (including policy tools and incentives) and a diversity of actors and decision-makers. In this situation it is not sufficient to only develop economic instruments and incentives and legal measures (see Box 20). These are important in framing governance efforts, but in order to deal with change and support social-ecological resilience and transformations, the governance structure itself needs to be understood (e.g. who are the stakeholders and what are their conflicts) and then navigated (e.g. facilitating management actions that are perceived as legitimate and fair) by relevant stakeholders. For example, inshore fisheries are typical common pool resources with potential for co-management. Despite that, the pattern of development across Europe is very uneven. In some countries, notably France and parts of the UK, there are well-established and highly structured statutory systems of local co-management; in many other countries however, formal systems are lacking. In Sweden there is, so far, no legal instrument delegating management responsibilities to stakeholders beyond what is valid for water owners in rivers and lakes and in specific areas of the east coast who have exclusive fishing rights (Píriz 2004, National Board of Fisheries 2007).

Building and co-ordinating the institutional and organisational landscape to enhance the fit between biophysical systems and governance is both time-consuming and complicated. Three related issues stand out as critical for success in this context: 1) institutional diversity and the need to link organisations across levels and initiating interplay among institutions; 2) the role of bridging organisations; and 3) the importance of leadership, which also raises the issue of legitimacy and mandate of the co-management initiative.


Photo: J.Lokrantz/azote.se

### BOX 20
### REVISITING PROPERTY RIGHTS REGIMES: A NECESSITY FOR ADAPTIVE GOVERNANCE AT LARGER LANDSCAPE AND SEASCAPE LEVELS

Much attention has been devoted to common-property regimes as alternatives to government-property or private-property regimes (e.g. Ostrom 1990, Bromley 1992). In common-property rights regimes, use rights, capital rights (rights to sell), management authority and excludability may be distributed differently for different ecosystem services. Yet as management's ecological level of concern increases, to catchment or landscape level for example, a mix of property rights regimes generally exists, along with the need for co-ordination to reduce spill-over effects in the form of external costs (e.g. pollution from one that harms all) and free-riding (e.g. those who do not invest in biodiversity may still benefit from others' investments) among stakeholders. Because of their interdependence, stakeholders cannot fulfil their objectives in isolation from the actions of other stakeholders (Imperial 2005). At the larger ecological scale, the challenges are shifting from designing property rights per se to agreeing on goals and strategies for responding to environmental change and hence to developing a more dynamic adaptive governance system.

## *Institutional Diversity*

A growing number of researchers argue that institutional diversity is important in preventing threshold effects in ecosystems. Low and colleagues (2003), for example, argue that redundancy and diversity in environmental and resource regimes can become a major source of stability and strength, in providing multiple ways of coping with or reorganising after change and unexpected events.

In addition, some researchers argue that institutional diversity provides risk-spreading and a greater range of options for responding to environmental change and disturbance (Low et al. 2003, Folke et al. 2005, Cummings and Norberg 2008). The argument is that apparantly redundant systems can compensate for human errors and for unpredictable changes in circumstances and the risks associated with »one-size-fits-all« solutions for common-pool resources (Becker and Ostrom 1995, Dietz et al. 2003). If there is institutional diversity, corruption at the local level (e.g. in a region trying to cope with illegal logging) for example, can be compensated for by action from higher levels – say, government and international intervention (e.g. Berkes 2002).

For vital components and functions, redundancy can be economically efficient; the costs of redundancy should be weighed against the costs of trying to design components and functions that »never« fail (which is unrealistic), the costs of failure and the costs of correcting failures when these occur. Streeter (1992) has referred to the back-up function of redundancy as »failure absorption rather than failure correction«. A recent example of institutional diversity is the emergence of different trading emission credits for carbon dioxide under the framework provided by the Kyoto protocol. As argued by Victor and colleagues (2005), the six parallel trading systems that have emerged from the «bottom-up« as the result of collaboration between state and private actors are effective not only to decrease emissions, but also to promote innovation and flexibility to changing circumstances.

Institutional diversity often implies that governance and management of natural resources is shared by many different democratic subunits of various sizes and scales, from national governments to local villages. If there is only one governance unit for a very large geographic area, then the area is vulnerable to external and internal environmental threats. These threats can be reduced in a region with multiple governance units organised at different levels. Subunits are allowed to experiment with different kinds of rules and policies. Citizens and officials have access to local knowledge, obtain rapid feedback and can learn from the experiences of parallel units, usually via higher-level units. The failure of one or more of these subunits to respond can lead to small-scale disasters that can be compensated by the successful reaction of other units in the area. Such poly-centric institutions are organised at multiple scales with different foci but with the capacity to compensate for failures that may occur at different scales (Ostrom 2005).

The notion of nested sets of institutions and the dynamic interplay between these also highlights how institutions can enable or stifle self-organisation and learning. It recognises the role of enabling conditions or legislations as an important part of adaptive governance approaches that support both centralised and decentralised governance modes.

Care must be taken when advocating institutional diversity to avoid fragmentation as well as reducing accessibility to decision-making arenas. Participating in these arenas is both costly and time-consuming. This makes it difficult for smaller or weaker stakeholders to participate actively – but these costs are lower for participation at a local level than they are for participation at a larger scale. This is particularly true for many developing countries that lack the means to send delegates to all of the environmental (and other) convention negotiations. For example, there is often only one delegate from many African and South American states while there can be up to 20 from Sweden (personal communication M. Schultz). These issues need to be resolved in order to prevent efforts towards institutional diversity from becoming exclusionary.

Organising linkages among institutions with relatively autonomous but interdependent actors and actor groups becomes crucial for avoiding fragmented and sectoral approaches to the management of biodiversity and ecosystem services. Researchers have observed the active role of a few key individuals or organisations in linking institutions at different administrative levels as, for example, in connecting local communities to outside markets (Bebbington 1997, Ribot 2004, Pomeroy et al. 2006). Crona (2006), for example, argues that middlemen, as buyers of fish from local fishermen and »informal micro-financing institutions«, constitute a critical link between fishers and markets in coastal communities of eastern Africa. Non-governmental organisations (NGOs) also frequently play the role of co-ordinators and facilitators of the institutional interplay needed for co-management processes (e.g. Halls et al. 2005) that can often improve or create good institutional fit. This needs to be encouraged and well-organised in order to address the problems identified in the previous paragraph. Also, intermediaries are no guarantee of more democratic decision-making and can play a role in the implementation of hierarchical command-and-control institutions where policies are applied in a top-down fashion (Gonzalez and Nigh 2005). These linkages need to be embedded in a larger structure that addresses accountability and legitimacy.

At the same time, employing adaptive governance through institutional diversity encounters several challenges in current governance systems. Institutionalist scholars point to path-dependency as one explanation for why institutions are not optimally fitted to new situations. Institutions are also typically long-lived, it is extremely hard to deconstruct existing institutions. This may lead to situations where several systems are at work simultaneously, with resulting inefficiency and confusion rather than the potential positive effects of institutional redundancy. We therefore have to learn not only how to create good new institutions, but how to deconstruct those that are dysfunctional. In complex institutional contexts, special care also needs be taken to ensure access and transparency. Otherwise, the legitimacy of participatory or bottom-up approaches may be reduced in the long-run, and the willingness of actors to participate decline if decisions are perceived to be taken elsewhere. Finally, institutional diversity also requires attention to the problem of accountability – how can decision-makers be held accountable in highly flexible, complex structures where actors shift over time?

### *Bridging Organisations and Collective Learning*

Bridging organisations are intermediaries tasked with establishing the institutional interplay typically necessary to achieve successful fit through adaptive co-management. A bridging organisation provides an arena for trust-building, social learning, sense making, identification of common interests, vertical and/or horizontal collaboration and conflict resolution – all central factors for adaptive co-management and adaptive governance (Cash et al. 2003, Folke et al. 2005; see Box 21). Boundary organisations are similar but provide a narrower scope, linking researchers and decision-makers (Guston 1999, Cash and Moser 2000). Such arenas and the collaborations they nurture can foster innovation, generate new knowledge, build experience with ecosystem change and identify new opportunities for solving problems (Malayang et al. 2006; these are key aspects identified in section 3.2.2.; see Box 22).

In this way, bridging organisations can play a key role in these collective learning processes. The collective learning process stimulates a »social memory« – a common knowledge pool of practical experiences that can be drawn on in community debate and decision-making processes when developing appropriate strategies for dealing with ongoing change (McIntosh 2000). Here a bridging organisation can be crucial for maintaining new collaboration among

### BOX 21
### LOCAL FISHERIES CO-MANAGEMENT IN SWEDEN AND THE PROBLEM OF INSTITUTIONAL FIT

The development of efficient co-management institutions takes time. In two municipalities in Western Sweden, local professional fishermen are the principal stewards of a (non-statutory) co-management initiative (SFI-Northern Bohuslän) with a mandate to participate in the management of a range of species, receiving support from the authorities. Fishing for lobster is very popular in the area and involves both professional and recreational fishermen from both within and outside the local communities. The pressure on the lobster stocks from the recreational fishery is commonly brought to discussion within the co-management initiative. The social complexity of the lobster fishing community, however, is not reflected in this initiative and the professional fishermen leading the co-management work are reluctant to take a leading role in this fishery. According to them, their involvement in any management action supporting the restrictions on recreational fisheries may lead to conflicts within their own social networks, which involve neighbours fishing and selling lobster on a recreational basis.

This results in institutional misfit as the institutions emerging from the initiative do not mirror the socio-ecological system. Due to this institutional misfit, management of the lobster fisheries is instead entirely in the hands of the central authority, which does not have the contextual knowledge needed to manage the fisheries in an adaptive way. The management of lobster, the involvement of recreational fishermen in this lobster co-management initiative is needed, and a bridging organisation could assist cooperation between these and the professional fishermen. Such an organisation could develop within the co-management initiative or the recently established marine national park in the area, Kosterhavet (personal communication L. Píriz 2009).

different stakeholder groups. Such learning processes require mechanisms for aggregating knowledge claims and interests among multiple actors. For ecosystem management there are several tools that can fill this function, for example, stakeholder dialogue and collaboration (Wondolleck and Yaffee 2000; Stubbs and Lemon 2001) and companion modeling (Trebuil et al. 2002).

In Kristianstads Vattenrike, Sweden, most environmental governance activities are coordinated, but not controlled, by Eco-museum Kristianstads Vattenrike, a small municipal organisation acting as a bridging organisation (Hahn et al. 2006). This organisation has developed an explicit approach to conflict resolution and dealing with disturbances (see Box 22).

### *Leadership*

Leadership is the third critical feature for increasing institutional fit through adaptive co-management (Young 2001). Key individuals can provide leadership and visions of ecosystem management and sustainable development that frame self-organisation, that is, self-monitored collective action assumed without being guided or managed by an outside source (Agranoff and McGuire 2001, Westley 2002). As such, key individuals are important in establishing functional links within and between organisational levels, thereby facilitating the flow of information and knowledge from multiple sources to be applied in the local context of ecosystem management. Leadership need not only be provided by a single person. It can also be provided by a group of stakeholders, or formal local and national managing authorities (see Box 23).

Co-management initiatives led by specific people or stakeholders clearly raise the issue of legitimacy, as they risk becoming captured by interest groups with priorities different from the overall societal interest (Brock and Carpenter 2007). Leadership has been shown to be of great significance for public network management. Network leadership and guidance differ greatly from the command-and-control style of hierarchical management (Agranoff and McGuire 2001). Steering is required to hold a network together (Bardach 1998), and the social forces and interests must be balanced to enable self-organisation (Kooiman 1993). Social-ecological systems that rely on only one or a few principal stewards, however, might not have the institutional capacity to prevent a misfit. Also mechanisms for defining mandate, balancing different interests, conflict mitigation and setting


## BOX 22

## KRISTIANSTADS VATTENRIKE BIOSPHERE RESERVE (KVBR) IN SWEDEN - AN EXAMPLE OF BRIDGING ORGANISATIONS

In the KVBR area, a number of projects have been initiated that aim at raising public awareness of the role of freshwater for ecosystem services and human well-being, of the threats to these services and of managing the landscape to support and enhance their provision. These projects emphasise humans as a part of ecosystems, humans' dependence on ecosystem services and the importance of maintaining critical functions and interactions in nature for maintaining the capacity of ecosystems to generate these services. They also aim at building an understanding of ecosystem dynamics into governance systems and emphasise the benefits of partnerships and proactively work with specific actor groups for conflict mitigation. A bridging organisation (BO), the Biosphere Office Kristianstads Vattenrike (formerly Ecomusem Kristianstads Vattenrike), has been created to serve as a bridge between various actors and interests, including local actors and governmental bodies.

This BO has a staff of five people and is part of the municipality's organisation; reporting directly to the municipality board, like a municipality administration, however, it has no power to make or enforce rules. Nevertheless, it has a strong legitimacy and trust among stakeholders (Hahn et al. 2006). Its sources of funds include the Municipality of Kristianstad, the County Administrative Board and the Swedish Environmental Protection Agency. The BO plays a key role as a facilitator and co-ordinator in the collaborative processes to maintain the ecosystem services of the area. It is involved in developing policy, designing projects, co-ordinating and administering conservation and restoration efforts and developing goals for the KVBR, as well as producing management plans, agreements, follow-up reports and updates for specific areas (Olsson et al. 2004, Hahn et al. 2006, Schultz et al. 2007). The BO plays a key role in responding to environmental feedback and developing new knowledge needed for managing the area. Examples include: managing floods, dealing with crop damage caused by increasing numbers of cranes and geese and the creation of social structures and processes to secure the continued cultivation of the flooded meadows.

## BOX 23
## CAN THE EU WATER FRAMEWORK DIRECTIVE (WFD) PROVIDE NECESSARY LEADERSHIP?

Policies for resilience should stimulate the creation of arenas for collaboration and management of social-ecological systems, with flexible institutions that allow for learning and building adaptive capacity. In this respect, the EU Water Framework Directive (2000/60/EC) seems to represent a substantial change in how Member States organise their management of water resources. Governance bodies are defined by the geographical boundaries of the ecosystem (drainage basin), rather than the geographical scope of these bodies. Moreover, the Directive encourages active involvement of all interested parties in its implementation, making room for social learning processes. However, the WFD also includes governance rationales of an expert-oriented, top-down kind that impede practical implementation of local initiatives (e.g. in Sweden the reporting requirement has led to the designation of larger water authorities than would be relevant from a local management perspective). The employment of different governance rationales (administrative, market, deliberative) in the same policy framework must be considered from the beginning of its formulation whereas the negotiations before the WFD led to an add-on approach. This means that technical regulation, pricing and participation are mixed without paying attention to the situations where the different approaches may collide with each other. While it is possible to employ different rationales in tandem, this needs to be done in a reflective manner.

Nevertheless, the Directive provides an opportunity to shift to more adaptive water management and governance approaches (Olsson and Galaz 2009). The new water authorities have an important leadership role to play in facilitating this transition. There is a need for new thinking and behaviour among managers and governmental officials as well as a need for innovative organisational and institutional arrangements that can enhance social learning. Central authorities could provide space and enabling conditions for learning networks to form, including financial, political and moral support. In the Netherlands transition arenas for shifting water management have been established (Van der Brugge et al. 2005). Central authorities also have an important role as activator and coordinator in such governance networks, facilitating cross-level inter-actions, synthesising lessons and incorporating them into national policies. New management and governance approaches should build on existing initiatives and their capacity to innovate, and redefine the role of central authorities to coordinate and help diffuse new insights and respond to events that go beyond the scope of local initiatives. A challenge will be defining the boundary of participation, with actors mobilised in relation to the issue to be addressed.

over-arching goals are thus critical challenges for central authorities wanting to stimulate co-management initiatives. Instead of super-imposing ready-to-use plans for ecosystem management on local contexts, the role of central authorities and agencies could then be to enable self-organisation through legislation, providing funding and creating arenas for collaborative learning (Berkes 2002, Olsson et al. 2004, Hahn et al. 2006). Folke and others (2003) refer to such an activator role as »framed creativity« of self-organisation processes.

### *3.2.4. Deal with the Unpredictable*

External perturbations, uncertainty and surprise are common in complex systems. Building on the previous three aspects, governance structures should also have the capacity to deal with unpredictable shocks or disturbances.

As seen in Chapter 2, biodiversity plays a crucial role in ecosystem resilience by spreading risks, providing »insurance« and making it possible for ecosystems to reorganise after disturbance. Similarly, as seen in the previous sections of this chapter, a diverse decision-making setting is critical to building resilience in social-ecological systems. Adaptive governance attempts to build resilience and increase the range of surprises with which a socio-economic system can cope. It does this by nurturing the diversity.

Recognising and accepting the uncertainty of future conditions is a central motivation for incorporating resilience thinking into governance. We are nowhere close to a predictive understanding of the complex interactions and feedbacks that govern trajectories of change in social-ecological systems, nor of anticipating the future human actions that will modify these trajectories. There are several sources of uncertainty, only some of which can be readily reduced. Both scientific research and the observations and experience of managers and resource-users provide data that inform our understanding of these systems. Models, both quantitative computer models and conceptual models of how the world works, also have many uncertainties in assumptions and structure. Surrounding these uncertainties in both data and models are uncertainties in other factors that we know to be important but for which we have neither data nor models – the »known unknowns«. There are also »unknown unknowns« that we cannot anticipate – the surprises that inevitably occur (Kinzig et al. 2003, Carpenter and Brook 2006, Carpenter 2009).


Local surprises tend to be manageable by individuals and groups of individuals (Gunderson 2003). There is a wide range of adaptations to risk that are economically rational to individuals, including risk-reducing strategies and risk-spreading or risk-pooling among independent individuals. Their detection requires a comprehensive systems perspective (e.g. an ecosystem rather than a single-species approach). These adaptation-to-risk strategies, however, tend to fail when cross-scale surprises occur, such as when local variables coalesce to generate an unanticipated regional or global pattern, or when a process exhibits contagion (as with fire, insect outbreak and disease). Cross-scale surprises often occur as the unintended consequences of the independent actions of many individual agents who are managing at different scales. Although individual responses are generally ineffective, individuals acting in concert can address these surprises if appropriate cross-scale institutions are available or are readily formed (see Box 24).

Truly novel surprises constitute never-before-experienced phenomena for which pre-adaptation is impossible. Directional change in the context of global and climatic change in combination with erosion of biodiversity creates a situation of increased likelihood of unknowable surprises. This said, systems that have developed mechanisms for nurturing the diversity – of species, of human opportunity, of learning institutions and of economic options –may be able to reorganise, learn and renew following sudden change, and thus cope effectively with true-novelty surprises. These are the social-ecological features that build resilience to deal with unexpected change.

Crisis, perceived or real, can trigger learning and knowledge generation (Westley 1995) and can open up space for new interactions and combinations

## BOX 24
## CAN THE INTERNET BE USED AS AN EARLY WARNING SYSTEM FOR POTENTIAL ECOLOGICAL DISASTERS?

Despite increasing improvement of ecosystem monitoring, early warnings of pending ecological crises is still limited by insufficient data and geographical gaps in official monitoring systems. Galaz and colleagues (2009) explored the possibilities of using information posted on the Internet as an early warning system to avoid crossing ecological thresholds leading to sudden losses of biodiversity and ecosystem services. The article points out that analysis and response are not necessarily organised around a single government actor. On the contrary, both might take place as the result of collaborations between different state and non-state stakeholders.

The study uses a range of examples from different ecosystems around the world to explore the untapped potential of web crawlers – software programs or automated scripts that browse the World Wide Web in a methodical, automated manner – in ecosystem monitoring. An early example of this was the use of an email-based coral list server used to disseminate and compile field observations tracking coral bleaching during the 1997-1998 El Niño event. This list server proved fundamental for prompt assessments of the global mass bleaching event, with reports ranging from detailed and accurately measured accounts to brief anecdotal reports from, for example, researchers. dive masters and fishermen.

The article focuses on three potential approaches in using web crawlers to forewarn ecological shifts. First, they can collect information on the drivers of ecosystem change, rather than the resultant ecological response (e.g. if rapidly emerging markets for high-value species lead to over-exploitation and collapse of a fishery, web crawlers can be designed to collect information on rapid changes in prices, landings or investments in particular regions). Second, but less certain, future web-based early warning systems might make use of the recent insight that ecosystems sometimes »signal« a pending catastrophic shift (e.g. variability of fish populations might increase in response to over-exploitation and indicate a possible collapse). Third, web crawlers may find ecological changes at small scales that warn of similar and larger shifts in other locations (e.g. early warnings of invasive species, as well as losses of smaller ecosystems that support the resilience of larger-scale ones such as for coral reef and forest ecosystems).

Galaz and colleagues (2009) warn that fragmented and potentially insufficient data might lead to information junkyards instead of robust ecological monitoring systems. Any web crawler-based monitoring system would therefore need a coupled knowledge management and expert judgment system.

In Sweden, a public Internet-based reporting system for species observations

(The Species Gateway, www.artportalen.se) has proven to be a success in respect to data collection. In seven years the system has collected over 19 million geographic observations of common species occurrence. Despite the fact that the system works without any formal quality control, the data collected could prove to be a very potent base for scientific research on changes in abundance and occurrence of common species as well as monitoring trends at population level by applying statistical scientific methods to correct for biases in reporting. Snäll and colleagues (2008) regressed data on 166 bird species collected 1996 – 2006 in the Swedish Bird Survey and in a checklist study against data from the Species Gateway. Data in the Species Gateway explained the inter-annual variation in the levels of population abundance in the Swedish Bird Survey and in the checklist study: the probability for a positive relation between the datasets was >92 %. The authors concluded that the vast amount of data on sightings of species reported by the public to Internet platforms can fill a gap among the tools for monitoring and assessing species diversity on different spatio-temporal scales. In particular, data on species that are of interest to the public, and that occur in habitats frequently visited by the public can be useful. The data collection and platforms also engage the public, something that forms a basis for future interest in biodiversity conservation and management.

of knowledge and experiences, as well as new management trajectories (Gunderson 2003). This capacity of human-natural systems to transform when conditions make the existing system unsustainable has been called transformability (see section 2.2; e.g. Olsson et al. 2004, Walker et al. 2004). It requires a capacity to learn, innovate and transform in periods of crisis. Bridging different networks and creating opportunities for new interactions is important for dealing with uncertainty and change, and is a critical factor for learning and nurturing integrated adaptive responses to change (Stubbs and Lemon 2001).

### *Climate Change and Uncertainty*

The challenges of climate change are in many ways related to dealing with perturbation, uncertainty and surprise. The IPCC assessments clearly show that the effects of climate change on people and ecosystems are not linear. The real world is much more complex as social-ecological systems undergo constant and dramatic change as a result of human activities and natural processes. Human settlements are built on exposed coastlines, on floodplains and in deserts. Political leadership, financial systems and demographics change over time, sometimes significantly and unexpectedly. These factors and many more contribute to the different levels of vulnerability of populations and ecosystems to the impacts of climate change. A tropical cyclone, for example, can have profoundly different effects in the United States than a similar storm in Central America.

The effects of climate change do not entail an entirely new set of challenges and problems, but they could severely aggravate existing ones. Accordingly, ecologically, socially and economically sustainable development policies and actions need to be even more emphasised in planning than they are today. Healthy functioning ecosystems that can buffer disturbances and provide ecosystem services essential for human well-being, such as water regulation, pollination and erosion control, are a prerequisite to handle adaptation to climate change. In this context there is a continuous need to put forward the importance of biodiversity for decreased vulnerability in local to global systems. Sound management of biodiversity and ecosystem services seems to be a cost-effective way to address the many uncertainties associated with climate change. These conclusions lead to the recommendations that measures taken in support of both adaptation to and mitigation of climate change should include the sustaining of biodiversity and ecosystem services as an important starting point, and that it is important to integrate the concept of ecosystem services and resilience and their connection to climate change into global governance regimes. It is, however, important to emphasise solutions that consider both social and equity aspects when working with these linkages (see Box 25). If values besides commercial values are not appropriately considered, then the pricing of ecosystem services like clean water, which can also be regarded as a human right, can, and has, lead to social conflicts.

Sterner and colleagues (2006) argue that reactive short-sighted responses to climate change and other large-scale environmental disturbances are all too common. Such policy responses, they write, tend to lead to uncertainty and surprises in flows of natural resources and ecosystem services to society. Often, the slow variables which are important for change, are given little regard, resulting in a simplified understanding of systems and a strong focus on optimisation and »quick fixes«. Narrowly-defined optimisation is dangerous in systems that exhibit non-linear dynamics (Sterner et al. 2006). This type of governance has to be replaced by risk-spreading and insurance strategies to maintain options and

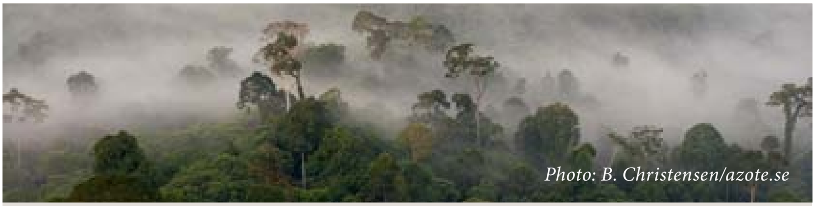


Photo: B. Christensen/azote.se

## BOX 25

### MANAGING FOR SYNERGIES IN AN UNCERTAIN WORLD

Below are examples of climate change mitigation measures that also address equity aspects of problems. More than one third of all greenhouse gas emissions are related to agriculture and forestry. The contribution from deforestation alone is approximately 20 % which is more than the emissions from the transport sector. Halting the unsustainable use of forests would, therefore, contribute substantively to reducing emissions, but ways and means on how to do this have to be thoroughly screened from an equity viewpoint. A possible REDD-mechanism (financial incentives for Reduced Emissions from Deforestation and forest Degradation) under the post-2012 framework of the Kyoto Protocol should consider effects on local communities and poor people (e.g. patterns of use and management of resources) and strive to ensure a fair sharing of benefits.

Support to the agricultural sector should promote methods that increase the ability of agricultural systems to adapt, to reduce the emissions of greenhouse gases and to contribute to risk distribution and decreased vulnerability. Examples of this include maintaining ecosystem services and a diversity of agricultural systems, crops and local varieties, with a broad spectrum of traits, in order to cope with more extreme and changing weather conditions. Increased levels of organic matter in soil can contribute to increased harvests and improved ecosystem services, such as nutrient cycling and water retention, but are also a way to sequester and store carbon and thus mitigate increased amounts of $CO_2$ in the atmosphere. A positive example of state-managed payments for ecosystem services is the the Swedish rural development programme (LBP) and its subsidy system in agriculture that pays for ecosystem services.

Support to coastal zone management should include maintenance of mangrove forests and coral reefs. Conservation of mangrove forests and coral reefs is an important and cost-efficient measure to protect coastal zones against weather-related catastrophes (storms and typhoons). It also benefits biodiversity and fisheries since spawning grounds for fish are preserved, and it is favorable for tourism. Similarly, wetlands have a buffering effect against drought and flooding under certain circumstances and can also function as carbon sinks, for example peat bogs.

sustain social-ecological systems in the face of surprise, unpredictability and complexity.

## 3.3. ADAPTIVE GOVERNANCE IN BIODIVERSITY-RELATED CONVENTIONS & MULTILATERAL AGREEMENTS

The above sections have identified a number of components that appear critical for the implementation of adaptive governance. These components have primarily been developed in local to regional contextual studies with a direct relation to the management of biodiversity and ecosystem services, but they could also potentially be applied to the governance of biodiversity and ecosystem services at higher levels within the governance framework. Below, we discuss these components in relation to biodiversity-related conventions and multilateral agreements.

The Convention on Biological Diversity (CBD) is one of the most comprehensive multilateral environmental agreements and one of the most important tools for international cooperation in the field of natural resource management (see Box 26). Other biodiversity-related conventions include the Convention on Migratory Species (CMS), the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the Ramsar Convention on Wetlands of International Importance and the World Heritage Convention.

Yet, all assessments carried out so far clearly indicate that we are not going to reach the 2010 biodiversity target. Although an abundance of information on biodiversity exists, there appear to be insufficient links between the science and the scientific and administrative bodies in biodiversity-related conventions to apply existing knowledge (UNEP 2009). Furthermore, gaps in basic knowledge of all aspects of biodiversity (genetic, species and ecosystem) still exist; both in regard to scientific data that can provide baselines to be measured against and organisations to handle continuous monitoring of trends. These knowledge gaps are more accentuated in many developing countries. In addition, institutional development to incorporate traditional knowledge in biodiversity management has been slow. Needs for capacity building for building knowledge relating to biodiversity, resilience and ecosystem services cannot be neglected by future policy.

A number of reasons have been suggested for the difficulty of reaching the CBD goals, including insufficient interchange between scientific assessments

## BOX 26

### CONVENTION ON BIOLOGICAL DIVERSITY

In 1992, the United Nations Conference on Environment and Development in Rio de Janeiro, Brazil took place. A historic set of agreements was signed at the "Earth Summit", including two binding agreements: the Convention on Climate Change, which targets industrial and other emissions of green house gases such as carbon dioxide, and the Convention on Biological Diversity, the first global agreement on the conservation and sustainable use of biological diversity (CBD COP V/6 and COP VII/11: www.cbd.int/ecosystem/). The biodiversity treaty gained rapid and widespread acceptance. Over 150 governments signed the document at the Rio conference, and since then more than 175 countries have ratified the agreement. The Convention has three main goals:

- The conservation of biodiversity
- Sustainable use of the components of biodiversity
- Sharing the benefits arising from the commercial and other utilisation of genetic resources in a fair and equitable way

The Convention is comprehensive in its goals, and deals with an issue so vital to humanity's future, that it stands as a landmark in international law. It recognises – for the first time – that the conservation of biodiversity is »a common concern of humankind« and is an integral part of the development process. The agreement covers all ecosystems, species and genetic resources. It links traditional conservation efforts to the economic goal of using biological resources sustainably. It sets principles for the fair and equitable sharing of the benefits arising from the use of genetic resources, notably those destined for commercial use. It also covers the rapidly expanding field of biotechnology, addressing technology development and transfer, benefit-sharing and biosafety. Importantly, the Convention is legally binding; countries that join it are obliged to implement its provisions. The Convention reminds decision-makers that natural resources are not infinite and sets out a new philosophy for the 21$^{st}$ century, that of sustainable use. While past conservation efforts were aimed at protecting particular species and habitats, the Convention recognises that ecosystems, species and genes must be used for the benefit of humans. This should be done, however, in a way and at a rate that does not lead to the long-term decline of biological diversity. The Convention also offers decision-makers guidance based on the precautionary principle that where there is a threat of significant reduction or loss of biodiversity, lack of full scientific certainty should not be used as a reason for postponing measures to avoid or minimise such a threat.

and policy creation, lack of political will, a poorly-informed civil society and business sector and weak national institutions. Despite the fact that overall knowledge about ecosystems and their importance for human survival has increased significantly in the scientific community, this knowledge has not been successfully presented in such a way that it has led to forceful political decisions. Often, there is a conflict between short-term financial gains and long-term sustainability, as well as an inadequate institutional capacity to meet international commitments. The sectoral responsibility for the conservation of biodiversity has, however, been given increased focus within the CBD in order to broaden responsibility to policy areas other than merely environment protection.

A number of initiatives within the EU are in progress to manage natural resources sustainably, both within the framework of common policies (the Common Agricultural Policy and the Common Fisheries Policy (CFP)), and in the framework of thematic strategies, for example the Commission's thematic strategy on sustainable use of natural resources. The former CFP, which contributed to the depletion of several economically important fish stocks, has been heavily criticised by several Member States and by the Commission. Its revision process (beginning in 2009 and due to be completed in 2012) has therefore been guided by a high ambition to create a fishing industry that operates within the ecological limits of its fishing grounds. The recently adopted EU Marine Strategy Framework Directive is an example of a recent EU decision that has the ambition to create a policy instrument that aims at achieving a cross-sectoral, integrated natural resource management beyond national borders and sector administrations. It requires the development and adoption of cross-boundary plans to manage regional seas, for example the Baltic Sea. The emphasis on the sectoral roles for conservation is in a number of respects a consequence of the international agreements that the EU has signed up to within the framework of the CBD, but also a result of an increased awareness that environmental problems and natural resource management cannot be addressed without a biogeographical approach and the application of measures across economic and political sectors. Other important legislative frameworks within the EU are the Water Framework Directive as well as the Habitats and Birds Directives implemented through the Natura 2000 network.

Several new European policies related to biodiversity conservation contain components that allow for adaptive co-management, for example, the river basin

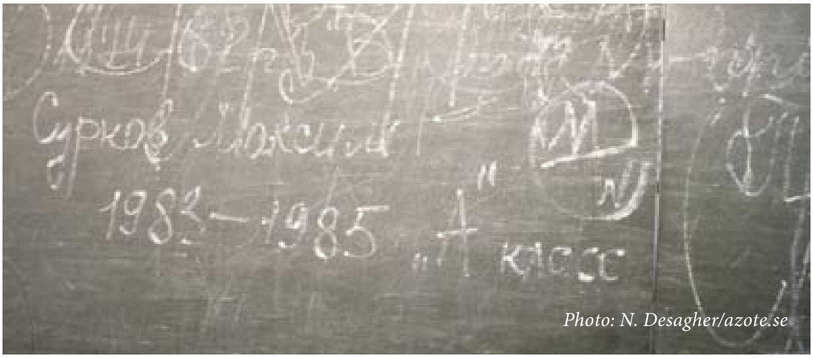


Photo: N. Desagher/azote.se

approach and the participatory ambitions in the Water Framework Directive. Partly due to their origin in a negotiation process, however, they also contain features that are expert-oriented and lean towards centralised solutions. Framing policies for future biodiversity governance in Europe would need to establish coherent frameworks for adaptive co-management.

### *3.3.1. The Building of Knowledge of Social-Ecological System Dynamics*

Despite the large number of biodiversity-related assessments carried out at different scales (e.g. the Millennium Ecosystem Assessment, the Global Environmental Outlook, the Global Biodiversity Outlook, the Global Forest Resources Assessment, the Global International Water Assessment and the International Assessment of Agricultural Knowledge, Science and Sustainable Development: UNEP 2009, table 3.1), a lack of understanding of biodiversity and the generation of ecosystem services persists, which is a substantial impediment to sustainable management of ecosystems. There is simply not, in many cases, enough scientifically validated information on how to sustainably extract natural resources from ecosystems without negatively impacting the provision of ecosystem services, nor/or sufficiently convincing evidence that biodiversity and functioning ecosystems are real limiting factors in the economical and social systems of society, nor/or mechanisms to convey existing information to policy-makers. This raises important questions of how we can manage biodiversity and ecosystem services when we do not fully comprehend how ecological systems are constructed or work. There is clearly a need to improve scientific understanding as well as create new arenas for the science-policy interface (UNEP 2009).

This said, the many recent global assessments relating to biodiversity and ecosystem services, at global and sub-global scales, have substantially contributed to the existing knowledge base. They have also increasingly aimed at being more integrated in the manner in which issues are assessed and cover a range of ecosystems. So far, there remains relatively little coherence between approaches to sub-global initiatives within and between scales (with the exception of those within the MA follow-up sub-global network). A wide variety of conceptual frameworks are used for design and implementation of assessments, although for recent integrated assessments at the global scale, and in many regional and national assessments, there has been an increasing use of the framework developed in the MA assessments.

These assessments have also increasingly been designed to be policy-relevant, credible and legitimate. Most recent and ongoing assessments evaluate both environmental and socio-economic factors, including status and trends of natural resources and their relationship with human development, other environmental issues and scenarios as well as response options (UNEP 2009).

Ongoing discussions in the scientific literature have raised concerns regarding the effectiveness of the current scientific advisory body to the CBD, questioning the legitimacy and independence of the scientific advice provided (Laikre et al. 2008). The need for credible and independent advice within the Convention has been highlighted, for example by the perceived politicisation on controversial issues such as biofuels.

The chairs of the scientific advisory bodies of biodiversity-related conventions (i.e. the CBD, CITES, CMS, Ramsar and World Heritage conventions) have recently (in 2007) started a discussion on areas of cooperation and collaboration on the scientific issues of the various convention processes and their translation into policy. They have agreed on practical cooperation on the issues of climate change and biodiversity and on the 2010 biodiversity target. The importance of a novel platform for the generation of legitimate, unbiased and synthesised knowledge has been raised by a number of stakeholders. There is an ongoing discussion regarding the possibility to establish a biodiversity- and ecosystem service-related version of the Intergovernmental Panel on Climate

Change (IPCC). This panel or platform has tentatively been called »IPBES«: an Intergovernmental Platform for Biodiversity and Ecosystem Services. The chairs of the scientific advisory bodies have concluded that: »There is abundant data and information on biodiversity but these data are often not available to the Conventions' scientific advisory bodies. If a need for IPBES is confirmed it should be ensured that its work focuses not on collecting additional data but on bringing together various sources of scientific information, including traditional ecological knowledge, in a coherent and comparable form.« (UNEP 2009)

### *3.3.2. The Use of Knowledge in Adaptive Co-Management*

The importance of using an adaptive co-management approach is underlined in the definition of the ecosystem approach within the CBD (Decision CBD COP V/6 and COP VII/11: http://www.cbd.int/ecosystem/). Realising adaptive approaches is, however, relatively rare and managers have a tendency to believe that further modelling and monitoring alone will resolve uncertainties, or that experimentation will be too costly and risky (Walters 1997). Other impediments may include opposition from special interest groups or an inability to resolve value conflicts among scientists and other stakeholders.

From a management and governance perspective, the 2010 targets are in many aspects inoperable. Firstly, the formulations are more visions than targets, since there are no baselines against which to estimate success or failure. A good illustration of the inoperability of the objectives is the limited number of global indicators used to assess success. The MDG follow-up only lists three indicators connected to the 2010 target, namely number of globally red listed species, the area of protected areas and the rate of decline in forest cover. Looking closer at the qualitative aspects of these indicators to assess what they are saying, the picture becomes unclear (see Box 27 and section 2.1.1).

Other issues of relevance include the monitoring of progress towards the goals, critical components for evaluating the effectiveness of adaptive management approaches. The third edition of the Global Biodiversity Outlook (GBO-3), which is due for publication in 2010, will provide an analysis of the achievement of the 2010 biodiversity target for policy-makers. The current indicator framework adopted by the CBD is recognised to be incomplete: reference to climate change as a threat to biodiversity is absent,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## BOX 27
### RED LISTED SPECIES AND FOREST COVER – ARE WE MEASURING THE RIGHT THINGS?

The number of species assessed against red list criteria comprise some 45 000 species out of which approximately 25 000 are well-documented and distribution maps are available for approximately 18 000 (IUCN Red List). These figures are negligible compared to current estimates of the total number of species globally, known as well as unknown, which is in the magnitude of several million. There is also a severe bias in the red list assessment towards terrestrial, and in particular forest, ecosystems. Also, among the better-documented species, there is a strong bias towards animals, rather than plants. In summary, our knowledge on species status at the global level is focused on a limited number of well-known organisms at a high systematic level in forest ecosystems. Furthermore, focusing on components (the species per se) misses their functional roles and the ecosystem dynamics supporting these species.

The forest cover assessment is based on a very general definition of land covered by a certain density of trees, without any detailed information of the ecological quality of these tree-covered areas (FAO Forest Programme, see also Box 11). Statistical information on the global area under protection (National Parks etc) also exists, which in this assessment is probably the most accurate indicator for biodiversity protection, although the management status of these protected areas is known to be very poor in many parts of the world.


measures of ecosystem integrity are insufficient and the linkages between biodiversity loss and the provision of ecosystem services are not adequately articulated or understood (Mace and Baillie 2007).

This means that current indicators only provide a very patchy description of biodiversity status since they do not include information on genetic diversity nor on ecosystems. More importantly, they do not include information on the status of ecosystem function and process. The conclusion must therefore be that no indicators of status and trends are available that give a reasonable basis for assessing in real terms the status of biodiversity and the ecosystem services it generates. The fact that natural ecosystems still are converted into different man-made systems at a high rate (e.g. forest cover loss and over-exploitation of most major fish stocks) can, however, be used as a good indicator of trend, although quantification of the negative trend is not possible with any reasonable certainty. This also raises the need for assessing interactions between social and ecological systems.

### *3.3.3. Flexible Institutions*

The growing awareness of the interdependencies between biodiversity and climate change, has triggered a number of new means of collaborations within and between the biodiversity-related conventions and multilateral agreements. This indicates that there is an increasing flexibility in these institutions and an acknowledgement of the need for and benefits of increased collaboration. The Biodiversity Liaison Group (BLG) was established to enhance coherence and cooperation in the implementation of the biodiversity-related conventions and consists of the heads of the secretariats of these conventions. In addition, the Joint Liaison Group (JLG) of the Rio Conventions (CBD, UNFCCC and UNCCD) was established in 2001 as an informal forum for exchange of information, exploring opportunities for synergistic activities and increasing coordination. The JLG comprises the officers of the conventions' scientific subsidiary bodies, the Executive Secretaries and members of the secretariats. The JLG has discussed cooperation on a range of issues including: adaptation, capacity-building and technology transfer; joint activities on information, education and awareness and research and systematic observation. So far, initiatives related to the reduction of deforestation and adaptation to climate change have been initiated, as well as coordination of scientific advice, methodologies and tools, by means of collaboration among the scientific advisory bodies to the conventions.

Both the BLG and JLG provide examples of frameworks for cooperation between conventions that have related subjects and objectives (and great overlap in participating Parties). The BLG in particular has been able to identify issues highly relevant for the harmonisation of scientific advice and to initiate further joint work on these issues. These collaborations (primarily horizontal) are strong indications of the increasing networking taking place between the conventions, which will hopefully increase the capacity to meet the biodiversity- and ecosystem service-related challenges.

### *3.3.4. Dealing with Uncertainty and Surprise*

It is widely known that the global community has responded too late to many environmental problems. A key feature in this has been the length of the lapse between problems being identified in science and a policy response being taken (EEA 2001). It is inherently difficult for policy and decision-making processes to adequately take account of emerging issues. Few of the ongoing global assessments provide flexible mechanisms to respond to demands from Multilateral Environmental Agreements for targeted or rapid integrated assessments on emerging issues relating to biodiversity and ecosystem services. Moreover, these assessments tend to have limited capacity to respond to emerging issues in such a way that they can effectively guide decision-making.


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There is, however, a growing number of horizon scanning exercises (i.e. a search for new and emerging issues of relevance for managing biodiversity and ecosystem services) being undertaken that aim to help in identifying and prioritising issues that may be of increased significance in the future. These may involve expert workshops and other forms of collaboration, looking at for example, market trends or emerging disease patterns. International and national initiatives are emerging specifically to assess the impact of future economic, social and environmental trends on biodiversity, and include the scenarios developed by the Millennium Ecosystem Assessment and the OECD International Futures Initiative (UNEP 2009, appendix 5). It is important to have multi-sector and multi-stakeholder discussions on emerging and future issues, particularly for highly contentious and controversial issues.


Photo: J. Lokrantz/azote.se

# Conclusions & Outlook

## CHAPTER 4

Formulating post-2010 biodiversity targets requires recognition of the dynamic interplay between biodiversity, ecosystem services and development in the context of rapid global environmental change. Needless to say, this is a very challenging task. This report has focused on describing the ecological context in which targets can and should be set – as well as the governance context in which targets are steered towards. Moreover, a successful post-2010 goal for halting biodiversity loss requires an agreement that communicates outside the biodiversity community and is understandable and relevant to poverty reduction and human well-being. It is also obvious that coherence between all biodiversity-related policy areas must be secured at global, European, national and local scales.

This Conclusions and Outlook section is neither exhaustive nor conclusive, rather, it aims to stimulate discussion of the substantial challenges in meeting the existing biodiversity targets identified in the report. These are closely related to: 1) the dominant worldview that fails to recognise how intimately interwoven humans and nature are in social-ecological systems, 2) knowledge production and mobilisation, 3) the will to experiment, innovate and learn (an adaptive co-management approach), 4) the capacity to support such experiments (flexible institutions in an adaptive governance setting) and 5) an openness to uncertainty and surprise (inherent to complex adaptive systems and due to the impacts of global change).

## 4.1 CHANGING THE CURRENT WORLDVIEW

Despite the significant scientific consensus on the occurrence and impacts of global change, including biodiversity loss, there is too little real action. If the notion of society as external to the environment rather than being tightly coupled to it prevails then actions to halt biodiversity loss and achieve a sustainable development will have limited impact and engagement will be short-lived. The concept of "ecosystem services" has, however, been a great tool in communicating the inter-dependence between social and ecological systems. The next, and ongoing, step is to quantify this dependence and understand the mechanisms behind this (see section 4.2) in order to better integrate this understanding into not only decision-making, but also how we do business. Already initiatives are emerging, for example the World Resources Institute has developed the Corporate Ecosystem Services Review. This is a methodology for corporate managers to proactively develop strategies for managing business risks and opportunities arising from their company's dependence and impact on ecosystems. This is a step in changing the corporate sector's view of the environment and their interaction with it, and a reminder that this shift must occur across sectors.

## 4.2. IMPROVING THE KNOWLEDGE BASE

In terms of the knowledge base from which to develop post-2010 biodiversity targets, there are two aspects in particular that need to be addressed: 1) completing knowledge of biodiversity and the management practices that sustain or degrade the long-term capacity of biodiversity in generating ecosystem services, but equally important is 2) mobilising and synthesising existing knowledge and coordinating future research efforts (see Box 28 for examples).

There are gaps in basic understanding, and these gaps become more important with the degree of complexity being assessed – from species identification to understanding and assessing resilience of social-ecological systems. As seen by the indicators presented in Box 4, the currently used indicators tend to overlook ecosystem interactions and dynamics (internally and across scales), limiting their usefulness in assessing the sustainability of ecosystem service provision. Nevertheless, several tools exist to address these challenges:


BOX 28

## SUGGESTIONS FOR IMPROVING KNOWLEDGE ON THE ECOLOGICAL UNDERPINNINGS OF SERVICE PROVISION AND THE METHODOLOGIES FOR ASSESSING ECOSYSTEM SERVICES AT MULTIPLE SCALES

- Quantifying the characteristics of biodiversity required to provide ecosystem services at different scales.

- Understanding interactions between ecosystems, ecosystem services and habitat, and determining whether minimum habitat area thresholds for the long-term provision of ecosystem services can be defined.

- Creating arenas for collecting local and traditional ecological knowledge, as well as means of improving the compatibility of different forms of knowledge.

- Developing methods for up-scaling local impacts and responses to landscapes and regions.

- Experiments on the effects of changing different components of biodiversity on ecosystem services at a management scale and 'natural experiments' based on real land-use situations.

- Promotion of systematic and formalised interdisciplinary research between the natural and social sciences.

## *Ecosystem Service Assessments*

Several recent ecosystem service assessments (e.g. MA 2005, TEEB 2008) focus on the capacity of ecosystems to provide ecosystem services and may be good enough indicators of ecosystem and biodiversity health. Furthermore, these assessments can be applied at different scales, allowing the identification of cross-scale influences of changes. They also permit monitoring of trends over time by establishing baselines to help formulate targets. Given their anthropocentric basis, they address human well-being, and are accessible to policymakers.

## *Assessing Resilience of Social-Ecological Systems*

The Resilience Alliance has developed two Workbooks for assessing resilience of social-ecological systems, one targeting practitioners in the field of natural resource management and the other for scientists familiar with the concept of resilience and system dynamics (The Resilience Alliance 2007a, b). These are available online and are designed as guidebooks, helping users through the assessments. This allows assessing social-ecological systems' resilience and can enable comparative and monitoring studies. Based on resilience theory, the assessment targets understanding a social-ecological system's dynamics and how changes in certain variables affect the overall functioning of both the social and ecological components of a system. This can again be more useful than individual indicators of for example species diversity.

## *A Framework for Analysing Sustainability of Social-Ecological Systems*

Ostrom (2009) has developed a framework for assessing social-ecological systems' sustainability. This framework is based on core sub-systems (in turn defined by a series of variables) and characteristics of a social-ecological system including the resource in question, the institutional setting as well as social settings, and their interactions. Given the very large number of combinations possible, this framework mirrors the complex reality of these systems rather than simplifying them to a few variables as done by most models. The advantages of this framework approach include that: it allows an assessment of existing knowledge of the system in question as well as providing an arena where researchers (and stakeholders) from different fields can share and join their understandings of the system; and it provides a basis for comparative studies to elucidate important variables (under certain conditions).

There is currently a high degree of political will to address climate change and biodiversity-related challenges. The salience of these issues can likely, in part, be attributed to the publication of the Millennium Ecosystem Assessment Report (MA 2005), the Stern Review on the Economics of Climate Change (2006) and the IPCC Fourth Assessment Report (2007). The scientific, political, public and private attention to the findings of these reports have contributed to stimulating the discussion on the establishment of an Intergovernmental Platform on Biodiversity and Ecosystem Services, an IPBES. This discussion has been based on the conclusion that there is a need to continuously build knowledge regarding biodiversity, resilience and ecosystem services and the linkages between these. The conclusion is that there is a gap between scientific knowledge and policy-making from local, national to global level and that there is a need for an interface between science and policy-making.

The main focus of IPBES should be to deliver timely and credible, evidence-based scientific and policy relevant information, mirroring the IPCC. As such IPBES is hoped to put the loss of biodiversity, ecosystems and their services at the top of the political agenda. The platform will need to work in close collaboration with the scientific bodies supporting the other biodiversity-related conventions and Rio conventions and also link to the MDG process. For the platform to have legitimacy and scientific integrity, it is likely important not to distract the activities of the panel with direct engagement in capacity building. Also the success of the platform will depend on an accepted process for nominating scientific experts, technical rigor and consistent methodologies for the assessment process and independent peer-review. After the first UNEP led stakeholder meeting in Putrajaya, November 2008, there has been substantial discussion about the context and scope of an IPBES. Clearly, there is a need for a consistent EU position on the establishment of an IPBES as support for the CBD and related biodiversity processes in time for the second UNEP dialogue in Nairobi, October 2009, coupled with a clear commitment to allocate funds for an IPBES, in particular for capacity building in third world countries which lack the capacity to fully and actively participate in scientific activities. The content of this report clearly emphasises the importance of a global, periodic assessment to secure evidence-based support to governance and management of ecosystem services and biodiversity, and thereby justify and support political leadership to implement measures and ensure policy coherence.

Another important issue is to improve knowledge on, and methodologies for, the valuation of ecosystem services, which has been taken up by TEEB, the global EU study on The Economics of Ecosystems and Biodiversity launched in 2007 as part of the Potsdam initiative. TEEB is now in Phase II, targeting policy-makers at national and local levels, businesses and consumers. Its findings should raise awareness of the value of biodiversity and effective action as well as the relative costs of inaction, and thus help the development of cost-effective policy responses. Phase II of TEEB is looking at all other ecosystems than forests; the only ecosystem valued in Phase I. A challenge for Phase II is building a framework on how to value ecosystems and biodiversity in the context of complexity, ecosystem and social dynamics, thresholds and resilience.

## 4.3. CREATING ROOM FOR ADAPTIVE CO-MANAGEMENT

Throughout this report we conclude that business-as-usual is simply not an option to solve the interacting local to global change challenges hitting and facing humanity. Furthermore, a number of small-scale, contextual studies have been presented in Chapter 3 that demonstrate the context-specific approach that management needs to take (and governance needs to support) versus blueprint solutions. The chapter discusses how an adaptive co-management approach can stimulate social learning and innovation, build trust and support resilience of social-ecological systems: all important for improving sustainability of social-ecological systems. Such initiatives are however relatively rare and need both supportive policy frameworks and a diversity of incentives to emerge. In line with this, adaptive European policies related to freshwater (the Water Framework Directive) and marine resources (the Marine Strategy Framework Directive) are currently being implemented. The EU Water Framework Directive (see Box 23), and its potentially conflicting components (top-down, technocratic ones and bottom-up, process-oriented ones), highlights the need for these new initiatives to be designed in a coherent manner to ensure long-term legitimacy (see also Box 29).

There is also potential for building a European research and development fund for adaptive co-management experimentations, coupled to a database and virtual knowledge-sharing tools in order to stimulate an adaptive approach within the European Community. The rationale for such a fund would build on the MA conclusion that the institutional capacity to deal with environmental degradation evolves more slowly than the pace of degradation. To meet this challenge, the purpose of such a fund would be to support flexible and large-scale experimentation, and co-ordinate smaller scale experiments, with innovative governance and management principles (that build resilience, reduce vulnerability and mitigate undesired change). These would be built on the indicators and assessments described in section 2.1.

BOX 29

### MEASURES TO IMPROVE THE POLITICAL AND INSTITUTIONAL KNOWLEDGE BASE

- Better communication and education so that general knowledge and acceptance of the key importance of natural systems are improved.
- Promoting public participation to set objectives for ecosystem service delivery in relation to stakeholder preferences and values.
- Investigating the risks associated with conservation based on ecosystem service delivery.
- Analysing the plurality of decision and communication contexts within societies and assessing the relative merits of different classification frameworks, evaluation methods and decision support tools for these contexts.
- Developing decision support systems to assist managers.

## 4.4. SUPPORTING CAPACITY BUILDING & FLEXIBLE INSTITUTIONS

The above-suggested fund for European adaptive co-management can contribute to building institutional capacity and consistent methodologies to research, and lead to improved implementation and follow up of European biodiversity-related policies. Funding is needed for collaboration, implementation and capacity building at all levels, from data collection to institutional capacity. The MA has contributed substantially to developing methodologies for conducting sub-global assessments of biodiversity and ecosystem services. However, substantial capacity building needs still exist in developing countries, implying that the ongoing follow-up process of the MA should include a substantial component of capacity building in developing countries, and the EU has an important role to play in providing financial support. The large global demand for capacity building also calls for a necessary partnership with private actors. For example, a large telecom company recently improved the infrastructure for 3G telephones throughout Africa. Interestingly, this infrastructure is also fitted with automatic measuring stations for climate-related variables and will contribute substantially to the knowledge base of African climate change. Analogous innovative support to scientific and administrative capacity should be encouraged.

Adaptive co-management and networks greatly increase the amount and flow of information and the demand for involvement of the scientific community and the authorities. This increase is particularly intense when the dominant management system is to be fed with one kind of information and a new system is emerging and generating different type of data and information (as described in Boxes 15 and 19). This situation is further complicated when a paradigm shift is occurring, for example a shift from management based on the interaction of professional fishermen with a single species to one based on interactions between various users and whole ecosystems. Hence, European academic and management systems should deepen their efforts in participatory research and support these changes by developing extension services (as described in Boxes 15 and 23).

## 4.5. DEALING WITH UNCERTAINTY AND SURPRISE

Moving away from steady-state approaches and blue-print solutions to more flexible governance structures and processes that acknowledge complexity is a demanding, but necessary, transformation for dealing with uncertainty and surprise of social-ecological systems. This challenge involves maintaining effectiveness of measures while investing in learning and experimentation. It involves nurturing a diversity of management and monitoring initiatives while finding common ground for coordinated actions to halt biodiversity loss and maintain ecosystem service provisioning. It involves continuously trying to reduce uncertainty by improving knowledge and monitoring, while also improving the ability to live with the uncertainty and surprises that are inherent of complex social-ecological systems. The IPBES discussed above could be an important mechanism for reducing uncertainty by identifying future trends, using technologies of horizon scanning, to discover emerging crises and thereby assist in preparing governments and regions in identifying response capacity to new issues. Living with inherent uncertainty and surprise requires institutional diversity, coordination and collaboration among actors and institutions, bridging organisations that can facilitate such collaboration and learning, and leadership.

The growing insights of the risk for abrupt human-induced environmental change at the regional and even global scale, raises new concerns of the risk of crossing tipping points in biophysical systems of the Earth that could cause deleterious or even catastrophic outcomes for humanity (see Box 6). Recent scientific advancement to address such large scale risks, has proposed a new planetary boundaries framework to allow for governance and management within a safe operating space, where human development occurs within defined boundaries for key Earth system processes. Biodiversity loss has been identified as one among nine key Earth System processes that, according to this research, qualifies as a planetary boundary. This framework, which combines scientific advancements in Earth system science and resilience research, provides new challenges for governance and management, particularly the capacity to deal with uncertainty and surprise, and to operationalise the precautionary principle.

*Photo: R. Kautsky/azote.se*

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# Glossary

ADAPTABILITY is the capacity of the actors in the system to manage resilience in order to stay within a desired state during periods of change.

ADAPTIVE CO-MANAGEMENT refers to the multilevel and cross-organisational management of ecosystems. Such multilevel governance systems of institutional interplay often emerge to deal with crises. They combine the dynamic learning characteristic of adaptive management with the linkage characteristic of collaborative management.

ADAPTIVE GOVERNANCE is understood as a concept that focuses on institutional and political frameworks designed to adapt to changing relationships between society and ecosystems in ways that sustain services provided by the ecosystem, e.g. fresh water or fertile soil. It implies collaboration among different agencies across multiple scales enabling ecosystem- that share power and (management) responsibilities

ALTERNATE STATE see regime shift

BIODIVERSITY is a short version of »biological diversity«. It is understood as the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic systems and the ecological complexes of which they are part. This includes diversity within species, between species and of ecosystems.

CAPITAL (see natural capital and social capital)

ECOSYSTEM SERVICES are the benefits that people derive from the ecosystem. These might include the production of goods e.g., food, fibre, water, fuel, genetic resources, pharmaceuticals, etc.; regeneration processes e.g., purification of air and water, seed dispersal and pollination; stabilising processes e.g., erosion control, moderation of weather extremes; life-fulfilling functions e.g., aesthetic beauty, cultural value; and conservation of options e.g., maintenance of ecological systems for the future.

ECOSYSTEM MANAGEMENT is an information-intensive endeavour and requires knowledge of complex social–ecological interactions in order to monitor, interpret and respond to ecosystem feedbacks at multiple scales

GOVERNANCE is a process involving the interactions of diverse public and private actors, their sometimes conflicting objectives and the instruments chosen to steer social and environmental processes within a particular policy area.

HYSTERESIS refers to how a system responds, or more specifically, the return path taken following some disturbance or change due to cumulative effects. When the system follows a different path upon return to its former state, this is called a hysteresis effect.

INSTITUTIONS are the humanly devised constraints that shape human interaction. These can be formal and informal.

NATURAL CAPITAL is an extension of the traditional economic notion of capital. The term was coined to represent the natural assets that economists, governments, and corporations tend to leave off the balance sheets. Natural capital can be non-renewable resources, like fossil fuels and mineral deposits; renewable resources, such as fish or timber; or ecosystem services (for instance the generation of fertile soils, pollination, or purification of air and water)

REGIME refers to a set of state in which a system exists while having the same basic structure and function. Most social ecological system's have more than one regime in which they can exist.

RESILIENCE is the capacity of a system to absorb disturbance and reorganise while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks.

RESPONSE DIVERSITY refers to the multitude of responses to environmental change and disturbances, among species contributing to the same ecosystem function. This kind of diversity plays a crucial role in sustaining the resilience of ecosystems to cope with disturbance and change.

SCALE is the spatial and temporal frequency of a process or structure. Scale is a dynamic entity. For the purposes of resilience assessment, a focal scale of the social-ecological system of interest is usually determined from among: landscape/local scale, sub-continental/subregional, continental/regional, and global scale, over a specified period of time.

SOCIAL CAPITAL refers to social relations and among individuals and the norms and social trust which they generate and which facilitate coordination and cooperation for mutual benefit (and hence can increase both individual as well as collective productivity).

SOCIAL-ECOLOGICAL SYSTEMS are linked systems of people and nature. The term emphasises that humans are a part of, not apart from, nature — and that the delineation between social and ecological systems is artificial and arbitrary.

SOCIAL LEARNING is learning that occurs when people engage with one another, sharing diverse perspectives and experiences to develop a common framework of understanding and basis for joint action.

SUSTAINABLE DEVELOPMENT combines Sustainability - the capacity to create, test and maintain adaptive capability and Development - the process of creating, testing and maintaining opportunity. Sustainable Development has also been described as fostering adaptive capabilities and creating opportunities. The goal of sustainable development is to create and maintain prosperous social, economic and ecological systems.

TRANSFORMABILITY refers to the interaction of the social and natural realm and is the capacity of people in a social-ecological system to transform that social-ecological system into a different kind of system.

VULNERABILITY refers to the propensity of social and ecological system to suffer harm from exposure to external stresses and shocks.

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This scientific background report concludes that halting biodiversity loss and sustaining ecosystem services for human well-being beyond 2010 requires recognition of the dynamic interplay between biodiversity, ecosystem services and human development in the context of rapid global environmental change. It calls for an improved knowledge base, increased use of adaptive management approaches in Europe, capacity building for such management and flexible institutions designed to deal with uncertainty and surprise.

The report is commissioned by The Swedish Scientific Council on Biological Diversity for the scientific workshop »Biodiversity, ecosystem services and governance – targets beyond 2010« on Tjärnö, Sweden, 4-6 September 2009. Report findings and the outcome of the workshop are intended to support deliberations at the high level conference »Visions for Biodiversity Beyond 2010 – People, Ecosystem Services and the Climate Crisis«, to be held in Strömstad, 7-9 September 2009, hosted by the Swedish EU Presidency. The overall objective of the Tjärnö workshop and the Strömstad conference is to prepare a revision of the Strategic Plan of the Convention on Biological Diversity, and in particular the development of new biodiversity visions and targets following the evaluation of the 2010 Biodiversity Target.

The report has been prepared by a working group led by the independent organisation Albaeco and includes contributions from a large group of national as well as international researchers and experts. The main contributors have been The Department of Aquatic Sciences and Assessment, at the Swedish University of Agricultural Sciences, and the Stockholm Resilience Centre, at Stockholm University.