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Sustaining Livelihoods and Human Well-Being during Social–Ecological Change

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Introduction

Social processes strongly influence the dynamics of social–ecological responses to change. In Chapter 2, we described the ecological processes that govern the flow of ecosystem goods and services to society. Sustainability of these flows depends not only on ecosystems, but also on human actions that are motivated, in part, by desires and needs for these services. Many of the social and ecological slow variables that determine the long-term dynamics of social–ecological systems act primarily through their effects on human well-being (see Chapter 1). Today humans are *the* dominant force driving changes in the Earth System, with the biophysical changes during the last 250 years so fundamental that they define a new geologic epoch—the **Anthropocene** (Crutzen 2002; see Chapter 14). Social process play a key role in driving these changes, so it is essential to understand them as critical determinants of sustainability from local to planetary scales. This chapter focuses on those social processes that affect well-being, society's vulnerability and resilience to recent and projected changes, and strategies for sustainable development that seek to enhance well-being, while sustaining the capacity of ecosystems to meet human needs. Institutional dimensions of well-being, which are also critical to sustainability, are addressed in Chapter 4.

Well-being, or quality of life, is more than human health and wealth. In the context of ecosystem stewardship and sustainability, well-being also includes happiness, a sense of fate control, and community capacity. **Livelihoods** of individuals and households include their capabilities, tangible assets, and means of living (Chambers and Conway 1991). Well-being and livelihoods are therefore key elements that set the stage for sustainability, resilience, and adaptability of people to change.

Livelihoods are both complex and dynamic (Allison and Ellis 2001). People both respond to and cause many ecological changes as a result of resource consumption by a growing population and efforts to meet their desires and needs in new ways. Perceptions of well-being are shaped by material conditions, history, and culture. For these reasons, the relationship

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between well-being, livelihoods, and natural and social capital can define the prospects for long-term sustainability (Janssen and Scheffer 2004). **Vulnerability,** the degree to which a system is likely to experience harm due to exposure to a specified hazard or stress (Turner et al. 2003, Adger 2006), and **resilience**, the capacity of a system to respond to and shape change and continue to develop, are important concepts in understanding these relationships (see Chapter 1). **Vulnerability analysis** has typically focused on the potential threats (e.g., climate change) and endowments (e.g., assets, social capital) that affect livelihoods and well-being (Turner et al. 2003), whereas resilience thinking has emphasized the capacity of groups to cope with ecological change and avoid dramatic and undesirable social–ecological shifts (Walker and Salt 2006). We integrate the vulnerability and resilience approaches in this chapter to provide a framework for understanding livelihoods and well-being in the context of ecosystem stewardship and argue that well-being based on adequate livelihoods is essential to reduce vulnerabilities to the point that people can engage in long-term planning for ecosystem stewardship**.** We also note that, because stakeholders differ in their values, perceptions of needs, and capacity to fulfill them, ecosystem stewardship requires a participatory place-based approach to improve well-being, plan for change, and cope with inevitable surprises (Maskrey 1989, Smit and Wandel 2006).

From Human Ecology to Sustainable Development to Social–Ecological Resilience

The context for understanding social–ecological interactions is shifting from studies of ecological effects on society (and vice versa) to development planning that presumes predictable effects on society to resilience-based stewardship that seeks to respond to and shape a rapidly changing world. The anthropological subdisciplines of human ecology, cultural ecology, and political ecology have studied the coevolution of human–environment relations and their effects on the well-being of human groups. These examinations have helped us to understand how ecosystems shape social organization, economies, and the exploitation of ecosystems and how human exploitation affects ecological conditions (Rappaport 1967, Turner et al. 1990). Anthropologists point out that, although each case is unique, there are common patterns that characterize types of livelihood strategies, such as sharing among hunting and gathering societies, specialized division of labor among family members in pastoralism, and specialization of technical skills in urban-based capitalism. The study of changes in these livelihood strategies has highlighted the current rapid changes in social complexity and emerging issues of disparity both within and across groups, particularly between those of developing and developed societies.

In the 1960s and 1970s, developed countries experienced a transformation in their thinking about resources use and environmental quality (Repetto 2006), in part because of the awareness raised by the books *Silent Spring* (Carson 1962) and the Club of Rome's *Limits to Growth* (Meadows et al. 1972). These books and several large environmental catastrophes, such as oil spills, captured the public's attention through mass media (Bernstein 2002). The global scope and consequences of environmental degradation from pollution and the central role of technology and population growth led to the UN Conference on Human Development in Stockholm in 1972, and later the UN Commission on the Environment and the Economy, which produced the historic document, *Our Common Future* (WCED 1987). Calling for the need to balance economic development with environmental quality, the commission popularized the term **sustainable development**, defining it as the means by which society improves conditions without sacrificing opportunities for future generations (see Chapter 1). The dilemmas of these potentially conflicting objectives have served both as a catalyst for discussions on sustainability, and the basis for fierce debate about the extent to which economic growth can provide for quality of life, while ensuring that ecosystem services are sustained to meet current and

future needs. These issues underscore the societal dilemmas represented by rising material consumption and current positive trends of population growth.

A dual focus on social–ecological resilience and well-being puts the debates on sustainable development into a dynamic context, raising questions about the sources of both social and ecological resilience available to groups seeking to shape change and navigate critical thresholds that may affect well-being (see Chapter 5). They also highlight the behavioral traps that may emerge and ultimately impede human development. The focus on vulnerability and resilience adds important insight to these discussions by directing attention to exposure to risks, potentials for shocks and pulses of change, and the capacity of the system to absorb and shape those forces. Although much of the sustainable development debate has focused on issues of well-being and livelihoods in the context of poverty, these issues have equally important implications for all societies and their life support systems. In the section below, we present information on current global trends in quality of life and describe some elements of well-being with relevance to ecosystem stewardship in a changing world. We also present an analytical framework for assessing vulnerability and resilience in the context of sustainable livelihoods, well-being, and social–ecological change.

Well-Being in a Changing World

Well-being integrates many dimensions of the quality of life. Disciplinary scholars, such as economists, anthropologists, and political scientists, typically focus on specific indices of well-being such as levels of consumption and expenditures, availability of employment for cash, sense of cultural continuity, and choice, respectively. Although each is important, so is a broader array, including one's sense of security, freedom, fate control, and good social relations (Levy et al. 2005, MEA 2005a). People differ in the ways that they define a sense of well-being, depending on culture, age, gender, household structure, and other factors. However, there is surprising agreement throughout the world that this broader array of elements is essential for a good life (Narayan et al. 2000, Dasgupta 2001). The social psychologist Abraham Maslow (Maslow 1943) framed well-being as a hierarchy of motivations, stating that basic physiological needs such as food and water are the most fundamental, followed by perceptions of safety and security, then love and belonging through social connections with family and community, then the need for self-esteem and the respect of others, and finally, self-actualization through pursuits such as creative action and reflective morality. Although Maslow's focus was mostly on individual motivation and well-being, there is an extensive literature linking individual and community resilience (e.g., Luthar and Cicchette 2000) that has logical consequences for social–ecological sustainability. Opportunities for sustainable stewardship increase as more of Maslow's components of well-being are met. In the following sections, we summarize the connections between these components of well-being and ecosystem stewardship.

Material Basis of Well-Being

The material basis of well-being includes people's essential needs, such as clean air and water and adequate food supply. Ecosystem services, generated at regional and local levels, contribute substantially to the material bases of well-being. Failure to meet the basic material needs of life generally has negative implications for ecosystems because people tend to prioritize the fulfillment of basic needs above long-term stewardship goals. In the absence of basic material needs, people are more likely to be trapped in perpetuating conditions of poverty, poor health, and social instability.

In the global aggregate, the *material basis* of well-being has increased substantially in terms of income and food supplies. **Gross domestic product** (GDP—a standard economic measure of income), for example, has doubled in less than 50 years and continues to increase in many regions. Much of the increase in income and associated consumption, however, has occurred

in developed nations and affluent segments of society, where consumption reflects desires and preferences rather than the fulfillment of essential material needs. However, in some areas there has been a genuine reduction in poverty. In East Asia income poverty declined by 50% between 1990 and 2005 (Levy et al. 2005). Yet, in about 25% of countries, particularly in sub-Saharan Africa, vulnerability as estimated by the Human Development Index is increasing (Fig. 3.1; UNDP 2003).

Economic disparity between rich and poor nations has increased since the beginning of the Industrial Revolution, a trend that continues today (Levy et al. 2005). In other words, poor countries are becoming poorer, relative to

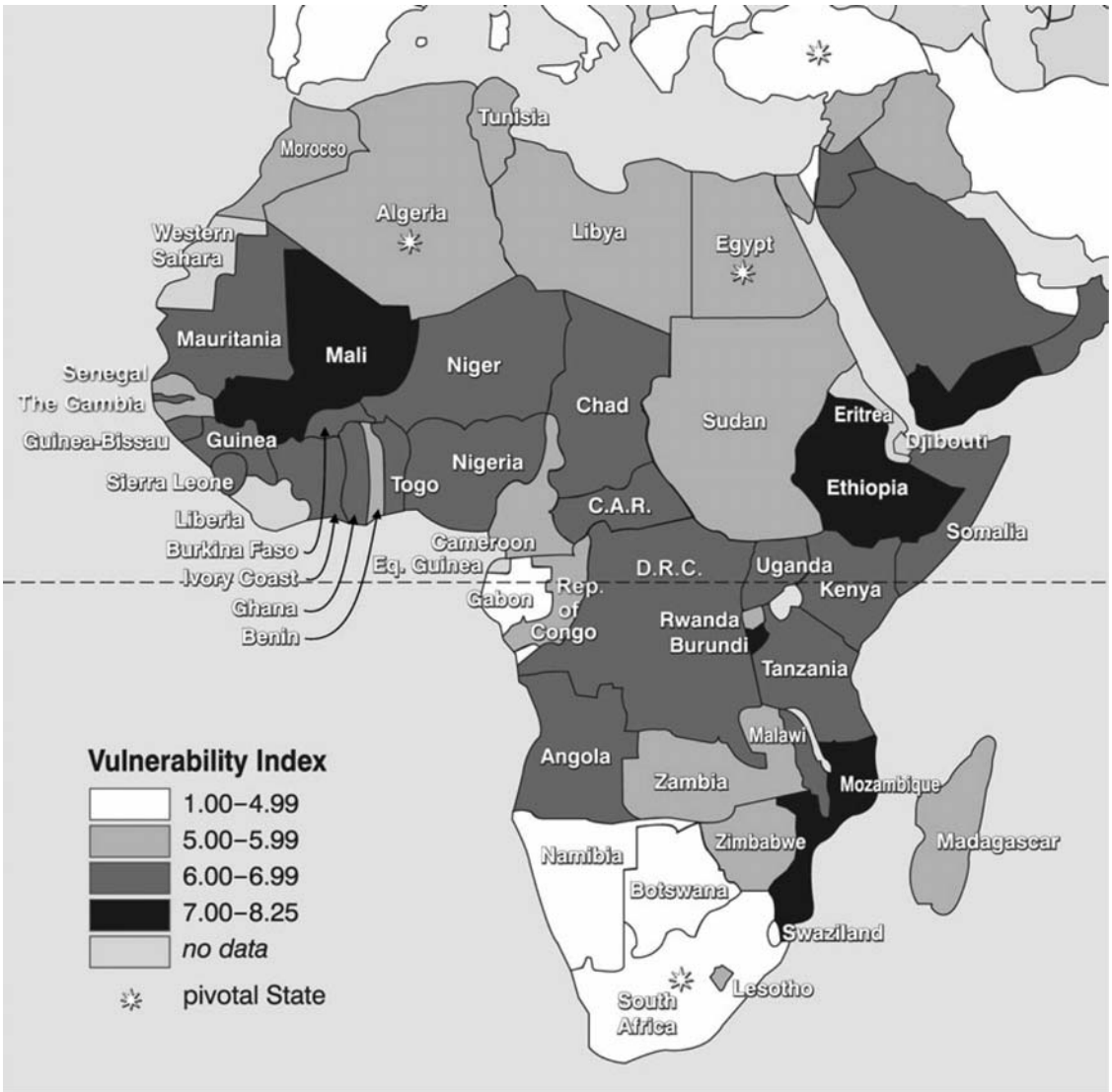

FIGURE 3.1. Vulnerability index for African countries, composed from 12 indicators (food import dependency ratio, water scarcity, energy imports as percentage of consumption, access to safe water, expenditures on defense vs. health and education, human freedoms, urban population growth, child mortality, maternal mortality, income per capita, degree of democratization, and fertility rate. Reprinted from Kasperson et al. (2005).

more developed nations. Within poor countries and some rich countries, economic disparity is also increasing. For example, as population increases, income has declined in low-productivity systems such as drylands, relative to more productive coastal areas (see Chapters 8 and 11). In extremely impoverished areas, people lack the resources to move to cities, which has been the predominant demographic trend in most of the world. Consequently, the greatest human pressure on the environment is occurring in those regions that are particularly prone to degradation of ecosystem services. Of the 20% of the global population that lives in poverty (here defined as living on less than $1 per day), 70% live in rural areas, where they depend directly on ecosystem services for daily survival (MEA 2005a). Large disparities between rich and poor can also create political instability and low resilience to shocks. These same regions of poverty and economic disparity are commonly subject to violent conflict, severe hardship, and chronic rates of high mortality.

Poverty and its implications for the degradation of ecosystems services can also have cascading and long-term effects on most other components of well-being. As people spend more time meeting their basic survival needs for food, for example, they have less energy to pursue education and other opportunities. Inadequate nutrition and education, in turn, can impact health and social relations. In about 25% of countries, the decline in natural capital has been larger than increases in manufactured plus human capital, indicating a clearly unsustainable trajectory associated with declines in assets for production (see Chapter 1). Many critical ecosystem services (e.g., pollination services, pest regulation, maintenance of soil resources) appear to be declining (Foley et al. 2005), although data gaps make it difficult to assess overall trends. This widespread decline in ecosystem services worldwide clearly threatens the future well-being of society, particularly the disadvantaged, and widens the gap between haves and have-nots.

The material basis for well-being is important but to some extent subjective. Below a per capita income of about $12,000, there is a strong correlation between the wealth of nations and the average happiness of their citizens (Diener and Seligman 2004). Similar correlations are observed within countries. There is, however, no significant increase in happiness once an individual's basic material needs are satisfied (Easterlin 2001). As people acquire greater wealth, they aspire to achieve even greater wealth, which, in turn, seems to reduce their happiness and overall satisfaction. In addition to the pursuit of consumption for its own sake, other factors become important once basic needs are met, such as the quality of social relations or one's sense of fate control. These findings suggest two basic approaches to achieving a better match between the flow of ecosystem services and the material needs of society: (1) assure that the basic material needs of poor people are met and (2) reduce the upward spiral of consumption by people whose material needs are already met.

Safety and Security

Perceptions of insecurity and risk vis-a-vis ecosystem services affect decisions that govern well-being. High risks of starvation, disease, armed conflict, economic crises, or natural disasters, for example, have psycho-social implications for all aspects of life and inevitably undermine society's commitment to ecosystem stewardship. Some hazards and risks have declined, and others have increased.

Stable livelihoods are one of the strongest determinants of safety and security. Lack of food security, in particular, is a critical component of well-being (IFPRI 2002; see Chapter 12). Families with insufficient income to buy food and no suitable land to grow crops are more vulnerable to environmental hazards that influence food supply than are people with greater access to these assets. Although the early literature on risk and vulnerability focused primarily on exposure to environmental hazards, there is increasing recognition that livelihood security is generally a stronger determinant of vulnerabilities and risks such as famine than are climatic events such as floods and droughts (Sen 1981, Adger 2006).

Clearly, basic material resources, security, and well-being are tightly linked.

Disease risk interacts with other components of well-being. In aggregate, human health has improved substantially. Reductions in infant and child mortality have contributed to a doubling of average life expectancy during the twentieth century. The associated increases in human population, however, augment demands for ecosystem services and nonrenewable resources and therefore rates of ecological change (Fig. 3.2). Changes in land use, irrigation, climate, and human settlement patterns in turn contribute to spread of infectious diseases that now constitute 25% of the global burden of disease (Patz et al. 2005). Most of these diseases are treatable, but ecological changes frequently increase the abundance or proximity of disease vectors, leading to high infection rates that overpower the medical capacity for treatment. Deforestation, for example, often brings forest animals in contact with livestock, increasing the risk of transfer of wildlife diseases to livestock and then to people; about 75% of human diseases have links to wildlife or domestic animals (Patz et al. 2004). Malaria, schistosomiasis, and tuberculosis are widespread despite active control programs. Other diseases such as trypanosomiasis and dengue in the tropics and Lyme disease and West Nile Virus in temperate countries are emerging health risks that appear related to climatic and ecological change. Current trends of climate warming create significant uncertainty about future trajectories of disease.

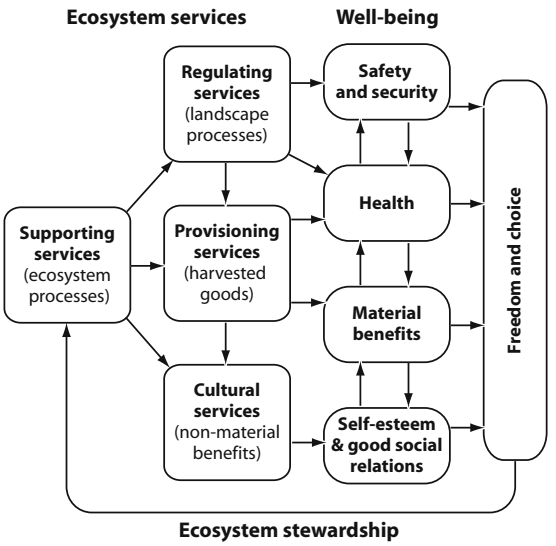

FIGURE 3.2. Relationship between ecosystem services and well-being. Adapted from the framework developed by the Millennium Ecosystem Assessment (MEA 2005d).

Several current global trends place increasing pressure on natural resources, adding risk to livelihoods and well-being: (1) an increasing human population, (2) a decline in basic environmental resources such as clean water, and (3) increasing demand for energy. The resulting increase in competition for renewable and nonrenewable resources substantially increases the likelihood of local and global conflicts. Oil-producing states, for example, now host a third of the world's civil wars (up from 20% 15 years ago), and half of the oil-exporting countries (OPEC) are poorer than they were 30 years ago (Ross 2008). Although there are international organizations (e.g., the UN), national and non-governmental organizations (NGOs), and treaties that could reduce the likelihood of conflicts, these are not always effective in the absence of basic social order. In summary, the risks of environmentally induced conflict are increasing, necessitating the adaptation and transformation of governance processes to alleviate these risks (see Chapters 4 and 5).

Many factors contribute to overall risk and insecurity, leading to social–ecological vulnerability. The impacts of climate change, for example, depend strongly on poverty and well-being. Sub-Saharan Africa will likely be much more vulnerable to climate change than will the drylands of Australia or the USA, even where the climatic changes and local ecology might be relatively similar. These differences arise out of the vastly different endowments that are available to people to deal with these challenges, for example, government services, better infrastructure, and more personal assets. The effects of drought on food supply may also be dramatically increased by civil strife. Wars accounted for about half of the major famines in the twentieth century (Hewitt 1997). Because vulnerability is always a multifactor social–ecological

problem, potential solutions should be place-based and pay careful attention to local context and slow variables such as climate, property rights, and livelihoods (Turner et al. 2003, Adger 2006).

Despite the complex nature of vulnerability, repeatable syndromes emerge (Petschel-Held et al. 1999). The Sahel and many other arid zones, for example, are characterized by a set of processes that result in the overuse of agriculturally marginal land and make people vulnerable to various hazards, including drought, war, and epidemics of AIDS/HIV. When patterns of correlation among 80 social and environmental symptoms of global change were examined, about 16 syndromes emerged that represented repeatable sets of interactions among these symptoms. These syndromes were categorized based on how humans were using nature: as a source of resources, a medium for economic development, and environmental sinks for human pollutants (Table 3.1). They provide a basis for identifying intervention strategies that might apply to broad categories of social–ecological situations. A combination of soil-conserving agricultural techniques and poverty reduction actions, for example, were thought to be most promising in reducing vulnerability in the Sahel of Africa and other similar social–ecological situations (Petschel-Held et al. 1999).

Good Social Relations

Good social relations involve social cohesion, mutual respect, equitable gender relations, strong family associations, the ability to help others and provide for children, and the ability to express and experience aesthetic, spiritual, and cultural values. These higher-order motivations (good social relations, self-esteem, need for mutual respect, and actualization) in Maslow's hierarchy are critical to ecosystem stewardship. They are the basis for **social capital**—the capacity of a group to work collectively to address and solve problems (Coleman 1990). One tangible measure of social capital is the extent to which social relations provide access directly to resources or to those with skills not held by individuals or members of a household. Social relationships and social capital are typically slow to build, but can deteriorate quickly, especially in times of rapid social or environmental change. Individuals and organizations interact through **social networks,** the

Table 3.1. Major patterns of social–ecological interactions grouped by the nature of human use of nature: as a source for production, as a medium for socio-economic development, or as a sink for outputs of human activities. Names are derived from either prototypical regions or catchwords for characteristic features. Adapted from Petschel-Held et al. (1999).

Nature as a source for production	
Sahel syndrome	Overuse of marginal land
Overexploitation syndrome	Overexploitation of natural ecosystems
Rural exodus syndrome	Degradation through abandonment of traditional agricultural practices
Dust bowl syndrome	Non-sustainable agro-industrial use of soils and bodies of water
Katanga syndrome	Degradation through depletion of nonrenewable resources
Mass tourism syndrome	Development and destruction of nature for recreational ends
Scorched earth syndrome	Environmental destruction through war and military action
Nature as a medium for socio-economic development	
Aral Sea syndrome	Damage of landscapes as a result of large-scale projects
Green revolution syndrome	Degradation through the transfer and introduction of inappropriate farming methods
Asian tiger syndrome	Disregard for environmental standards in the course of rapid economic growth
Favela syndrome	Socio-ecological degradation through uncontrolled urban growth
Urban sprawl syndrome	Destruction of landscapes through planned expansion of infrastructure
Disaster syndrome	Singular anthropogenic environmental disasters with long-term impacts
Nature as a sink for outputs of human activities	
Smokestack syndrome	Environmental degradation through large-scale diffusion of long-lived substances
Waste-dumping syndrome	Environmental degradation through controlled and uncontrolled disposal of wastes
Contaminated land syndrome	Local contamination of environmental assets at industrial locations

linkages that establish relations among individuals, households and organizations across time and space (see Chapter 4). Networks can also serve important functions at the landscape scale, as for example in the regulation of water use for rice production in the Balinese water temple networks (Lansing 2006). It is therefore important to avoid evaluations of well-being and livelihoods that focus solely on individual conditions. The social processes that form the basis of social relations and their underlying social networks (See Chapters 4 and 12) are some of the critical endowments that define the sensitivity of a household, community, and society to risk and vulnerability.

Self-Esteem and Actualization

Fostering self-esteem and providing outlets for actualization of creative abilities and actions motivated by a person's sense of place provide some of the greatest opportunities to enhance ecosystem stewardship. The highest-order elements in Maslow's hierarchy of human motivations, self-esteem and self-actualization, are most fully expressed when people have met their immediate material needs, feel secure in their capacity to continue meeting these needs, and have strong social relations. Wealth, however, is not a prerequisite for these higher-order motivations. Many preindustrial cultures found time and ways to express their relationship with the environment (e.g., Coastal Indians of the Northwest Coast of North America) through art and the celebration of stories that are part of oral traditions. When basic needs are met, there is a sense of fate control, and people feel a sense of group and space to practice and appreciate music, literature, theater, and others arts that embody the importance of people's relationship with ecosystems. These activities help to embed stewardship as a part of culture by providing the social space for reflection on the value of ecosystems and people's relationship with their environment. People's appreciation for their relationship to nature (i.e., a land ethic; Leopold 1949) is often a strong motivation for ecosystem stewardship and sustainability and can be a powerful stabilizing feedback for managing rates of change.

As noted above, well-being and ecosystem stewardship are defined primarily around issues of social conditions, yet Maslow's work was to a great extent focused on the individual. Indeed, ecological stewardship depends substantially upon individual resilience—the capacity of individuals to cope with change while remaining healthy. Although the connections of individual resilience and ecosystem stewardship may seem distant for professional resource managers, they are nonetheless worth considering when implementing and evaluating specific programs and policies. Where communities face epidemic rates of suicide or substance abuse, addressing issues of individual resilience under conditions of rapid socioeconomic change may prove to be the key to community-scale resource stewardship.

Assessing Vulnerabilities to Well-Being

Vulnerability is the degree to which a system is likely to experience harm due to exposure to a specified hazard or stress (Turner et al. 2003, Adger 2006; see Chapter 1). Social dimensions of vulnerability are intimately tied to elements of well-being, particularly to livelihoods; safety and security; and strong social relations. In this section, we link the concepts of livelihoods and well-being to social–ecological vulnerability in a rapidly changing world (Fig. 3.3). Vulnerability analysis includes three evaluative steps: identifying (1) the type and level of exposure of a system to hazards or stresses, (2) the system's sensitivity to these hazards based on the social and economic endowments available to them, and (3) the adaptive capacity of the system to make adjustments to minimize the impacts of hazards (Turner et al. 2003, Adger 2006).

An important strength of vulnerability analysis is its focus on specific hazards and their interactions and on the differential impacts of these interacting hazards on specific social groups at a specific place. Vulnerability analysis of poor coastal communities of Bangladesh to climate

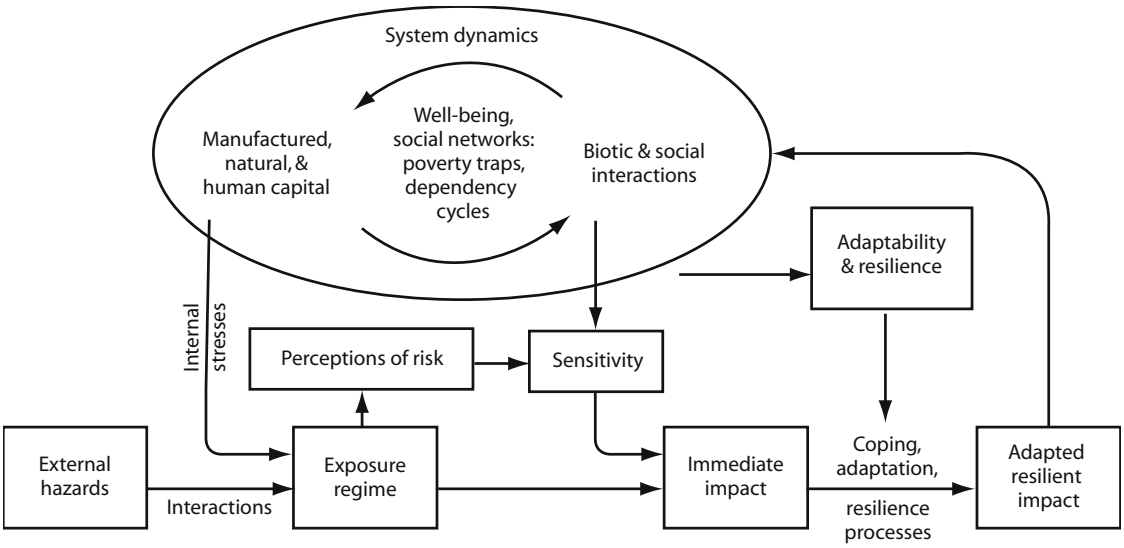

FIGURE 3.3. Components of vulnerability. Vulnerability depends on exposure to external hazards or internal stresses; sensitivity of the system to these interacting stresses; and the adaptive adjustment in response to the resulting impacts.

change, for example, would consider the intensity and frequency of storm surges (exposure); the capability of local infrastructure to withstand storms and flooding (infrastructure sensitivity); and the capacity of the community to mobilize resources in anticipation of the storm and capacity of aid workers to arrive at the scene after the incident has resulted in damage (social sensitivities). The goal of vulnerability analysis is to provide the type of information necessary for targeted intervention strategies that foster adaptation to changing conditions.

Exposure to Hazards and Stresses

Social–ecological systems experience hazards that depend on both external events and internal dynamics. Exposure is the nature and degree to which the system experiences environmental or socio-political hazards (Adger 2006). **Mitigation** (reduction in exposure to a hazard) is therefore an important strategy for reducing vulnerability. Hazards can be characterized in terms of their magnitude, frequency, duration, and spatial extent (Burton et al. 1993). Exposure can reflect **exogenous hazards** that a system experiences (e.g., heat waves, earthquakes, tsunamis, colonization, wars, novel market forces) or **endogenous stresses** (e.g., food or water shortage, lack of financial resources, high levels of internal conflict; Turner et al. 2003, Kasperson et al. 2005), or both. Internal stresses often reflect scarcity of one or more forms of capital or other components of well-being (Fig. 3.3). Hazards, whether they be exogenous or endogenous, can range from events or pulses that shock the system, such as an earthquake or collapse of a financial market, to chronic stresses that undermine well-being and social–ecological integrity of the system, such as rising sea level from climate change or increased energy cost.

Exogenous Hazards

The increased frequency of extreme events adds to the vulnerability of social–ecological systems. Model simulations suggest that human-induced climate warming contributes strongly to many environmental components of this trend (IPCC 2007a, b; see Chapter 2). Extreme heat killed 35,000 people in Europe in 2003, for example, and extreme droughts are occurring more frequently. Flooding is also

occurring more frequently in low-lying countries like Bangladesh. Increased sea-surface temperatures may intensify tropical storms, perhaps contributing to their fourfold increase in frequency. Melting of sea ice makes hunting of marine mammals more hazardous for arctic subsistence hunters (Krupnik and Jolly 2002). Each of these changes exposes people to more severe environmental hazards.

Climatically induced disturbances are integral components of social–ecological systems, so exposure to these disturbances is shaped by both exogenous climate and endogenous social–ecological interactions (see Chapter 2). The frequency and extent of wildland fire, flooding, and pest outbreaks, for example, are increasing in response to climatic warming, but the extent to which people are exposed to these disturbances also depends on management decisions. Frequently, there is public pressure to prevent these changes by increasing effort to suppress wildland fires, building larger flood control structures, and using pesticides to reduce populations of pests and diseases (see Chapter 1). In the short term, these policies may reduce exposure, but in the long term, they increase the risk of larger, more severe disturbances (see Chapter 2; Holling and Meffe 1996). An important arena of policy debate is therefore how best to minimize vulnerability that results from climatically induced increases in exposure to disturbances. In some cases there are potentially simple solutions such as policies that minimize development in floodplains or fire-prone wildlands. In other cases, policies designed to reduce exposure simply shift the vulnerability to certain segments of society (typically the disadvantaged) that occupy the lands with greatest exposure to hazards. Active public discourse on these issues can provide the basis for evaluating vulnerabilities and informing those potentially affected.

Air and water pollution also increase the hazards to which people are exposed. As with climatically sensitive disturbances, disadvantaged segments of society tend to live and work in places where they experience greater exposure to these environmental hazards. In some cases regulatory and market approaches can reduce the release of pollutants into the environment and therefore the exposure of society and ecosystems to their effects. For example, international treaties such as the 1987 Montreal Protocol, which banned the use of ozone-destroying chlorofluorocarbons (CFCs), led to a decline in the production and use of these compounds. As with all long-lived pollutants, there has been a long lag-time in the decline in atmospheric concentrations of CFCs in response to these "cleanup" policies. The rate of ozone destruction by these compounds is only now beginning to decline, 20 years after policy implementation. This indicates the importance of acting early to reduce pollution, as soon as environmental consequences are identified. There is currently active debate and experimentation with market mechanisms and regulatory limits to the quantities of CO_2 that a country or firm can emit. In summary, there are a variety of regulatory and market mechanisms, as well as the necessary technology, to reduce vulnerability to pollution. Unfortunately, there are often strong economic incentives at the levels of nations, regions, and firms not to pay the cost of pollution mitigation or to continue polluting illegally (see Chapter 4). Reducing vulnerability to pollution is thus more of a political and social issue than a scientific challenge.

Economic globalization increasingly links economic stresses in vulnerable nations to global economic fluctuations. Although these links may improve living conditions in the short run, they may also create vulnerabilities as communities become dependent on services supplied by central agencies. Food aid, for example, can eliminate markets for local farmers, leading to a decline in the in-country capacity to produce food (see Chapter 12).

Endogenous Stresses

Endogenous stresses are affected by both ecological and social processes (Kasperson et al. 2005). Declines in ecosystem services (e.g., the productive capacity of soils, the filtration of pollutants by wetlands, and pollination of food crops) exposes people to shortages of food and clean water. Such shortages interact

with socioeconomic factors to contribute to the vulnerability of some segments of society, as described in general in Chapter 2, and in greater detail in Chapters 6–14. Similarly, chronic poverty and or the lack of freedom to make lifestyle choices are stresses that contribute substantially to vulnerability of disadvantaged segments of society. *Exposure* to endogenous stresses is difficult to separate from *sensitivity* to these stresses, so we treat both exposure to endogenous stresses and sensitivity as sources of vulnerability in the next section.

Sensitivity to Hazards and Stresses

Sensitivity to hazards and stresses depends on ecological (see Chapter 2) and social sensitivity (previous section on livelihoods and well-being), as well as the degree of coupling between social and ecological components of the system. A group with a high dependence of locally harvested crops and limited interaction with cash markets, for example, may have a high sensitively to drought. Sensitivities can also depend on economic and social conditions (e.g., wealth stratification, strength of social capital, infrastructure availability), or power relationships (e.g., caste systems).

Group members with greater authority and influence generally command more resources and are therefore less sensitive to hazards and stresses. Within a given location, people of different race, gender, and age generally differ in their power to access resources and/or to influence decision making. Women, children, and disempowered ethnic groups, for example, usually have less access to resources, and this difference in livelihood makes them more vulnerable to hazards and stresses. For example, ties to children and social norms associated with travel may limit the mobility of women in some regions of Asia, whereas men have greater mobility to pursue jobs in urban areas. Livelihoods and power relationships are deeply intertwined, and together determine **entitlements**, which are the sets of alternative resources that people can access by legal and customary means, depending on their rights and opportunities (Sen 1981, Adger 2006). Entitlements depend in part on the availability of resources in terms of built, human, and natural capital and in part on institutions and power relationships that allow people to access resources (see Chapter 4).

Power relationships can vary geographically. People living in remote areas generally have less influence to affect change than those in urban or government centers. Similarly, those in inner city ghettos are marginal to those in more wealthy suburbs (see Chapters 8 and 13). These power relationships can translate into higher vulnerabilities to environmental shocks of people at periphery (e.g., high dependence on central government support for crisis relief) than those at core areas (Cutter 1996; see Chapter 8). Nonetheless, those at the margin may also have options for subsistence harvesting in conditions of scarcity that are unavailable to the rich and poor of the inner cities. The distinctions between exogenous and endogenous stresses are difficult to tease apart in an increasingly connected world, where local groups with sufficient resources can garner regional-to-international support for their needs and interest through use of the media, policy communities, and strong leadership (Young et al. 2006). While a greater connectivity and stronger voice can improve conditions for those at the margin, the power imbalances remain.

Cycles of Dependency

Endogenous stresses can be exacerbated when repeated patterns of dysfunctional social behavior become reinforced through time. **Cycles of dependency** are often precipitated by welfare or land-use policies that can lure individuals, households, and entire communities away from traditional livelihood practices into systems with disincentives for self-sufficiency, instead of the safety net or development that is intended. In many regions of the underdeveloped world, cycles of dependency have been linked to the philanthropic activities of NGOs, which result in unanticipated consequences. The resulting conditions can entrap individuals and in some cases entire social groups, increasing their vulnerabilities to change. Breaking

patterns of dependency is not easy and needs to consider the broader social–ecological context. For example, in the 1880's loss of traditional livelihoods by several Native Americans tribes of the US West and the resulting cycles of dependency resulted from both the tribes' exposure to foreign pathogens (e.g., small pox) and the Manifest Destiny policies of the US government. Because it is impossible to restore fully any social–ecological system, finding a way to escape from these patterns for Native Americans of the US West requires an integration of both traditional and novel solutions. Development of credible and responsive institutions that support self-determination of those affected is an important ingredient in escaping dependency (see Chapter 4).

Social and Environmental Justice

The impacts of social and environmental changes are unevenly distributed both locally and globally, making some regions and segments of society more vulnerable than others. E**nvironmental injustice**—the uneven burden of environmental hazards among different social groups (Pellow 2000)—results from differences in both exposure and sensitivity. For example, the arctic, mountains, and drylands, where climatic change is occurring most rapidly and climatic extremes shape local culture and adaptation, are more exposed to the risks of climate change than are some other regions (McCarthy et al. 2005). Similarly, there is a net transport of persistent organic pollutants to high latitudes, where they are further concentrated through food chains in animals harvested for food by indigenous residents (AMAP 2003). Local variations in exposure also occur, especially for point sources of contaminants and pollution and for risks such as flooding that are locally heterogeneous. Disadvantaged segments of society are often most exposed to environmental hazards because they lack the resources to avoid exposure to existing hazards or lack the political influence to prevent hazards from increasing.

Those groups that are most exposed to environmental hazards are also disproportionately sensitive to these hazards, because they lack the material resources and safety from risks to cope and adapt effectively. These same individuals are also frequently disengaged from and in many cases disillusioned with the political process, or lack the power to make their voices heard. Consequently, addressing the issues of social and environmental injustices generally requires a concerted and personalized effort to engage stakeholders in the decision-making process to solve problems.

Sources and Strategies of Resilience and Adaptive Capacity

Sources of resilience in social systems provide people with the means to buffer against change. Sources of resilience can be material, social, cultural, ecological, and intellectual. Resilience can also follow from a group's capacity to innovate in the face of new or rapidly changing social–ecological conditions. The central issue here is to avoid innovations and adaptations socially and economically that provide short-term benefits at the cost of the longer-term capacity of ecosystems to sustain societal development.

Spectrum of Adaptive Responses

Social–ecological systems exhibit a broad spectrum of responses to hazards and stresses. These responses range from the immediate impacts of hazards and stresses without adaptation, to short-term coping mechanisms, to adaptation or transformation, in which adaptive responses foster favorable long-term social–ecological adjustments. As described in the previous section, the **immediate impacts** of hazards and stresses are a product of interactions between the exposure and sensitivity of the social–ecological system. Although, by definition, immediate impacts involve no adaptation, they differ regionally and among segments of society largely due to differences in poverty and well-being.

Coping is the short-term adjustment by individuals or groups to minimize the impacts of hazards or stresses. Coping mechanisms enable society to deal with fluctuations that fall within the normal range of experience (Fig. 3.4; Smit and Pilifosova 2003). Coping sometimes occurs by drawing on savings or social relationships, for example, by harvesting animals at times of drought or famine, borrowing from neighbors or family after a flood, or relying on extended social networks during a regional crisis. However, stresses that occur over a sustained time period can lead to a decline in the availability of these resources. Alternatively, an increase in the population that is dependent on these resources constrains a system's coping capacity and the range of conditions with which it can cope (Smit and Wandel 2006). Other factors that reduce the coping range include external events and political factors (e.g., wars or loss of a leader) and increased frequency of stresses (e.g., drought).

Adaptation is a change in a social–ecological system that reduces adverse impacts of hazards or stresses or takes advantage of new opportunities (Adger et al. 2005). In this way, adaptation acts as a stabilizing feedback that confers resilience and reduces vulnerability. Adaptation occurs through social learning, experimenting, innovating, and networking to communicate and implement potential solutions (Fig. 3.5). These processes depend critically on patterns of social interactions and group behavior, which are the main subjects of Chapter 4. **Adaptive capacity** refers to preconditions that enable adaptation. Adaptations can differ in many ways. For example, they can be reactive, based on past experience, or anticipatory, based on expected future conditions. Adaptation can also be local or widespread; technological, economic, behavioral, or institutional (Smit and Wandel 2006). There is a continuum in the degree of adjustment and complexity of adaptation ranging from simple coping strategies by individual actors to complex system-level changes. Some authors prefer to treat the entire spectrum of adjustment as "adaptation" (Gallopin 2006). Substantive adaptation often requires a substitution among forms of capital or a reorganization of the institutional frameworks that influence the patterns of use of manufactured, human, and natural capital. Hence, adaptation is a continuous stream of activities, actions, decisions, and attitudes that inform decisions about all aspects of life and that reflect existing social norms and processes. Adaptation for resilience requires directing a social–ecological system in a way that provides flexibility and responsiveness in dealing with disturbance and that allows a way to take advantage of the latent diversity within the system and the range of opportunities available (Nelson et al. 2007).

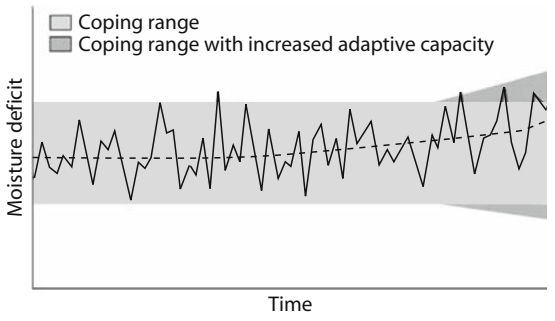

FIGURE 3.4. Coping range and extreme events. Redrawn from Smit and Wandel (2006).

Transformation is the conversion to a new, potentially more beneficial, state with new feedbacks and controls when existing ecological, economic, or social structures become untenable (Fig. 3.5; see Chapter 5). Transformation in the social context may include radical changes in governance, such as the American Revolution or the fall of the Soviet Union or shifts from an extractive to a tourism-based economy. There is often a tension between efforts to fix the current system and a decision to cut losses and move to a qualitatively different structure (see Chapter 1; Walker et al. 2004). This is discussed in Chapter 5 in the context of social–ecological transformation.

Fostering Diversity: Seeds for Adaptation and Renewal

Diversity provides the raw material or building blocks on which adaptation can act (Fig. 3.5).

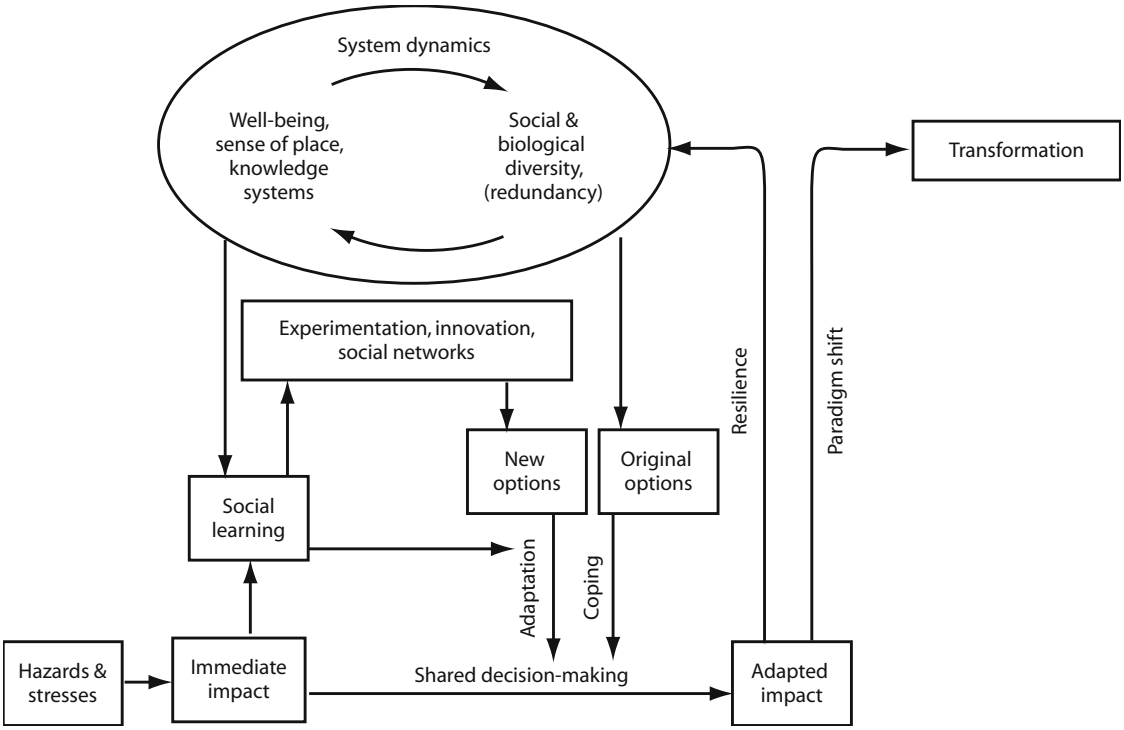

FIGURE 3.5. Components of adaptive capacity and resilience. Adaptive capacity depends on capacity to cope with the normal range of variation in hazards and stresses and the capacity to adapt through social learning, experimentation, and innovation.

It increases the range of options, at least some of which are likely to be successful under whatever new conditions arise, thereby reducing the likelihood of radical degradation of the system. It also provides **redundancy**, that is, multiple means of accomplishing the same ends, which augments the likelihood that valuable functions will be retained during times of rapid change. Chapter 2 describes the role of biological diversity in fostering resilience and adaptation. Economic and social components of diversity can also be important. The role of diversity in social–ecological resilience is well-illustrated in economics. Economic diversity reduces vulnerability and facilitates adaptation to economic or environmental change (Chapin et al. 2006a). For example, a nation whose economy is overly dependent on a single product is vulnerable to changes in the demand for, or value of, that product. Economic diversity can be enhanced by incentives that encourage entrepreneurship and initiation of new types of businesses. This role of subsidies contrasts strikingly with their more typical role in supporting production in sectors that have been adversely affected by climatic, ecological, or economic change (see Chapter 10). Agricultural subsidies in Europe and the USA, for example, typically support the continued production of crops that would otherwise not be able to compete on the global market with foods produced by countries with lower labor and production costs. In some cases, subsidies for non-competitive sectors of the economy are maintained simply because of the political power of groups that benefit from them. In other cases, there may be good reasons to subsidize traditional sectors. Scandinavian countries, for example, support agriculture in part to maintain an agricultural capacity as insurance against global or regional conflicts that might interrupt food imports. Agriculture or other traditional activities may also be subsidized for their cultural value to society, as in the case of agriculture in northern Norway.

Once decisions have been made to provide incentives to foster economic innovation and

diversity, there are many potential mechanisms to accomplish this, including "carrot and stick" combinations, voluntary agreements, and tax incentive schemes (Baliga and Maskin 2003). Investment in education and infrastructure can increase the capacity of local residents to diversify their economy and explore options. Economic diversification potentially enhances resilience because it is unlikely that all economic activities would be equally sensitive to any given change in the natural environment or in economic and political conditions.

Diversification of livelihoods is a common strategy among groups in anticipation of stressors and shocks to the system (Ellis 1998). Most rural peoples have considerable experience managing exposure to risk that occurs within "normal" levels (Fig. 3.4). The development of diverse portfolios of livelihood strategies among members of a household or kinship group is common. Diversification may include, for example, planting a variety of crops because of uncertainty in crop yields or markets. Another form of diversification is the cash employment by one or more members of a household in an off-site enterprise while remaining members work family-farm operations. A similar role diversification is found among some contemporary hunting cultures where some family members work full-time jobs while others are full-time subsistence harvesters, sharing their take with the extended family.

Diversification can include strategies other than increasing sources of cash. Households may build their resilience by intentionally extending their social networks to new groups that can provide additional resources or potential support in times of hardship. It is noteworthy that diversification can be used by both the wealthy and the poor and can contribute to equities and inequities. The elimination of constraints that allow for choice in diversification can enhance adaptive capacity and reduce vulnerabilities (Ellis 1998). Diversification of livelihoods may broaden the capacity of a group to cope with change (Fig. 3.4), but its effectiveness may be limited if the shocks to the system are extreme. The capabilities of rich versus poor households to diversify are also categorically different (BurnSilver In press). Well-off families usually have the benefits of larger asset portfolios on which to diversify their activities, and this can lead to greater wealth stratification between wealthy and poor over time.

The role of cultural diversity in social–ecological resilience is complex. As with economic and biological diversity, cultural diversity provides a range of perspectives and approaches to addressing problems (see Chapter 4). For example, industrial fishing typically uses nets with a single mesh size capable of catching all large fish, while allowing small fish to escape. In contrast, Cree Indians in Canada use mixed-mesh nets that allow escapement of a range of size classes. The single-mesh nets are much more efficient at catching valuable fish. However, large fish are also disproportionately important in reproduction so, as fishing pressure increases, the loss of large fish can decimate the fishery (see Chapter 10). The diversity of fishing approaches provided by two cultures proved important in conserving the fish on which the Cree depended (Berkes 1995). Sometimes, however, cultural perspectives are so radically different or are so strongly rooted in historical conflict that cultural diversity creates more challenges than opportunities, especially where institutions for shared decision making are lacking. The major point here is that cultural diversity broadens the range of perspectives and experiences with which to address change.

Institutional diversity provides a range of mechanisms for fostering innovation and implementing favorable outcomes and will be discussed in Chapter 4.

Legacies and Social Memory: Latent Sources of Diversity

Social legacies and social memory contribute to resilience by providing insight into the alternatives for responding to disturbance and change. **Social legacies** are the lasting effects of past events affecting current social conditions. **Social memory** is the collective memory of past experiences that is retained by groups (Folke et al. 2003; see Chapter 4). Because it endures longer than the memory of individual people, it contributes strongly to resilience and

sustainability. Social memory includes both the written record (e.g., books, articles, reports, and regulations) and oral traditions and stories of events, strategies for coping with those events, and their lasting lessons. Thus, social memory provides a wealth of ideas on how social–ecological systems and their components have responded and adapted to changes in the past. This memory extends the range of potential future options beyond those that dominate the current system (Fig. 3.5). For example, the stories and memories of elders of many cultures provide historical accounts of coping strategies as well as insights that inspire innovation in problem solving. Social memory can be particularly important in times of crisis, when current options, by definition, are insufficient, and a broader range of possibilities is essential to discover pathways to favorable outcomes (see Chapter 4). Social memory constantly evolves in response to system change. Social memory is important because it provides a context in which to frame novelty and change (Taylor 2000).

People who are negotiating social–ecological systems that are subject to disturbance and change may draw on their internal social memory as sources of resilience for renewal and reorganization. Others may use diverse memories and recombine them in ways that lead to social–ecological transformations through, for example, new inventions or leadership with new visions or worldviews.

Individual actors, communities, and whole societies may successfully adapt to changing social and economic circumstances in the shorter term, but such an adaptation may be at the expense of the essential capacity of ecosystems to provide support in the longer term. For example, the unprecedented expansion of human activities since the Second World War made possible through the exploitation of fossil energy has in many respects been an impressive human adaptation, with numerous local and regional transformations (see Chapter 14). However, the cumulative effects of these changes have contributed to global climate change in the present.

To what extent can social memory contribute to such adaptations? People's knowledge of resource uses and ecosystem dynamics is often tacit or implicit, linked to norms and rules, embedded in rituals and social capital, and framed by worldviews and belief systems. This is true for both **traditional knowledge** and the **local knowledge** of contemporary societies. It is also true for the more formal science-based approaches to knowledge production. Having the capacity to tap into a group's local and traditional knowledge, while cultivating its development, is fundamental for integrating livelihoods and well-being into resilience-based ecosystem stewardship. In many local communities there are management practices with tacit ecological knowledge that respond to ecosystem feedbacks in ways that can enhance social–ecological resilience (Berkes and Folke 1998a, Berkes et al. 2000). Yet as sources of resilience, legacy and memory are subject to interpretation. Indentifying key individuals in a group who hold a rich understanding of the events of history and facilitating group processes that lead to reflection on past experiences can provide access to these sources. Through social learning, actors, networks, and institutions can integrate traditional knowledge with current practices to find new ways to collaborate (Schultz et al. 2007).

Innovation and Social Learning: Creating and Sharing New Options

Learning to cope with uncertainty and surprise is a critical component of adaptive capacity. Individuals and groups are generally familiar with short-term variability in the hazards and stresses to which they are exposed and have coping mechanisms and adaptations that do not require learning new things. However, when stresses or conditions change directionally (or variability increases) and move beyond past experience, people may lack the social memories and legacies to formulate an effective response. Learning is therefore essential to deal with **surprises**—unanticipated outcomes or conditions that are outside the normal range of variability. There are at least three potential responses to surprise (Gunderson 2003): (1) **No effective response** occurs when inertia or

ineffectiveness in resource management prevents a response or when vested interests block changes that are attempted. This preserves the *status quo* and maintains or augments vulnerability. (2) **Response without experience** occurs if actions are taken in response to novel circumstances or if institutions fail to incorporate understanding gained from previous experience. The outcomes from inexperienced responses can be good, bad, or neutral. (3) **Response with experience** occurs when **social learning** has retained insights gained from previous experiences (Fig. 3.5; Lee 1993, Berkes and Folke 2002). It occurs through the retention and sharing by groups and organizations of knowledge gained from individual learning (see Chapter 4). Social learning is therefore important in increasing the likelihood that the system will respond based on experience and understanding of system dynamics. Social learning can occur in many ways. Considerable learning occurs through the cumulative experience gained as local knowledge by observing, managing, and coping with uncertainty and surprise. It can also occur through scientific research or by reading or hearing about the experiences of others. Local knowledge is critical for effective implementation of new solutions because it provides information about local conditions or "context" that determine how to implement new actions effectively. Local knowledge also incorporates people's **sense of place** reflecting how people relate to the social–ecological system in which they are embedded and therefore how they are likely to respond to, or participate in, potential new approaches to ecosystem stewardship.

Social learning that contributes effectively to social–ecological adaptive capacity almost always requires the integration of multiple perspectives and knowledge systems that represent different views about how a system functions (Fig. 3.5). Examples of complementary perspectives and knowledge systems include the natural and social sciences; academics, practitioners, and local residents; and Western, Eastern, and indigenous knowledge systems.

Resilience learning is a form of social learning that fosters society's capacity to be prepared for the long term by enhancing its capacity to adapt to change while maintaining and sustainability. Like other forms of social learning, resilience learning benefits from cumulative experience, learning from others, and integration of diverse perspectives and knowledge systems. However, resilience learning is particularly challenging because it requires that individuals collectively consider the interactions of different components of the entire social–ecological system, rather than a single aspect such as forest productivity or poverty, which are complex suites of issues in their own right. The core of resilience learning is developing the social mechanisms to make decisions that enhance long-term sustainability and resilience under conditions of uncertainty and surprise. This is radically different than a paradigm of postponing decisions until the group believes that it knows enough not to make mistakes. The latter approach is never sufficient for addressing long-term complex issues and is often used as an excuse for avoiding short-term risks and maintaining the *status quo*. The decision *not to take action* is just as explicit a decision as acting decisively.

There are at least two important components of resilience learning: The first is to reduce uncertainty and improve understanding of the dynamics of social–ecological systems under conditions of variability and change so as to explore new options. This can occur through observation, experimentation, and modeling (see Chapter 4). The second is the process of social learning that requires **framing** the issues of sustainability and resilience in a context that conveys its value to the public and to decision makers (Taylor 2000).

Research on complex adaptive systems is challenging because everything changes simultaneously, and you can only guess what future hazards and stresses may be. There are, however, logical approaches to improved understanding of resilience by (1) identifying critical slow variables, (2) determining their responses to, and effects on, other variables (often nonlinear and abrupt); and (3) identifying processes occurring at other scales that might alter the identity or dynamics of critical slow variables.

There are typically only a few (about 3–5) slow variables that are critical in understanding long-term changes in ecosystems (Gunderson and Pritchard 2002). Critical slow variables are frequently ignored, assumed to be constant, or taken for granted by policy-makers, who tend to focus on the fast variables that fluctuate more visibly and are often of more immediate concern to the public. The dynamics of ecological slow variables were discussed in Chapter 2. The identity of critical **social slow variables** is currently less clear but probably includes variables that constrain well-being and effective governance. Critical social slow variables are often stable or change slowly over long periods of time, but may change abruptly if thresholds are exceeded. For example, property rights of many pastoral societies in Africa changed abruptly as a result of European colonization and policy debates over how to promote pastoral development, causing changes in land use, social disruption and declines in well-being (Mwangi 2006). Oil development or building fences to create game parks for ecotourism can today cause similar disruption to pastoral livelihoods. Many of the factors that disrupt well-being were discussed earlier in this chapter, and factors influencing governance are addressed in Chapter 4.

Interactions among key variables operating at different scales are also important causes of abrupt changes in social–ecological systems (Gunderson 2003). For example, interactions among changes in global climate and local population density may cause soil loss in drylands to exceed the changes that would occur based on either factor acting alone. Research and awareness of processes occurring at a wide range of scales (e.g., the dynamics of potential pest populations to behavior of global markets) can reduce uncertainty and enhance resilience (Adger et al. 2005, Berkes et al. 2005). Often these cross-scale effects are difficult to anticipate, so managing to maintain or enhance resilience of desired social–ecological states may be the most pragmatic approach to minimizing undesirable effects of cross-scale interactions.

Planning for the long term requires an understanding of the tradeoffs between short-term and long-term costs and benefits. Actions that contribute to long-term sustainability often incur short-term costs. For example, managing forests or economies for diversity usually incurs short-term costs in terms of reduced efficiency and profits. Monospecific single-aged forest plantations, for example, can be harvested efficiently, and the harvested material can be transported and processed to produce one or a few products, with substantial economies of scale. These plantation forests are, however, more prone to losses from windthrow, disease, and changes in global markets than are more diverse multi-species stands and therefore lack resilience to long-term changes in these hazards and stresses (Chapin et al. 2007; see Chapter 7). Substantial social learning must occur before people or groups are willing to look beyond the short-term costs and benefits to address long-term resilience and sustainability. In economic terms people tend to discount future value to such a degree that many decisions are based primarily on short-term rather than long-term benefits. Politicians may be interested in maximizing benefits over their term of office (a few years), and community planners seldom think beyond 5–20 years. Resilience learning requires a reassessment of these discount rates and exploration of new options that extend the time horizon over which benefits are valued by society. This is most likely to occur if strategies are developed that maximize **synergies** (win-win situations) and reduce the magnitude of tradeoffs between short-term and long-term benefits (see Chapter 1). Now may be the best time in history to convince society of the importance of long-term thinking because the magnitudes of directional changes that previously occurred over many generations (centuries and millennia) are now evident within a single human lifetime due to the accelerated rates of change and increased human longevity (see Fig. 1.1).

Incorporating Novelty in Social–Ecological Systems

Experimentation and innovation allow people to test what they have learned from observations and social learning. Managers are often

reluctant to engage in social–ecological experiments under conditions of uncertainty because of the risk that outcomes will be unfavorable to some stakeholders (see Chapter 4). An alternative approach is to learn from the diversity of approaches that inevitably occur as a result of temporal and spatial variation in land ownership, culture, access to power and resources, and individual ingenuity. Multiple suburbs of a city or school districts within a region, for example, represent different efforts to address a common set of problems. In general, this diversity in approaches leads to improved levels of performance, despite the inefficiency associated with redundancy (Low et al. 2003). Similarly, social–ecological differences between production forests, multiple-use forests, and wilderness conservation areas provide opportunities to learn about resilience to climatic, ecological, and economic shocks and openness to innovation and renewal (see Chapter 7). As expected in complex adaptive systems, those experiments that are successful persist, and the failures disappear. Social learning further increases the likelihood that successful solutions will be adopted by others. Providing opportunities for a diversity of social–ecological approaches spreads the risk of failure and the motivations for success.

Networking increases the efficiency of social learning. Two essential features of adaptation in any physical, biological, or social–ecological system are the presence of a diversity of components and the selection and persistence of those components that function effectively. In social–ecological systems, diversity is created through experimentation and innovation, and selection occurs through the process of **governance**—the pattern of interaction among actors that steer social and environmental processes within a particular policy arena. System-level adaptation requires that successful innovation to cope with surprise be communicated broadly, so other people and groups can avoid the mistakes of unsuccessful experiments and build on the successes. These decisions and innovations take place at the level of livelihood choices of groups and individuals. Identifying successful options requires leadership and appropriate participation to select adaptation strategies and an appropriate governance structure to share information and resources and implement solutions. These topics are central features of Chapters 4 and 5.

Participatory Vulnerability Analysis and Resilience Building

A key challenge of applying vulnerability and resilience frameworks to ecosystem stewardship is developing qualitative and quantitative measures of the framework elements. It is also important to move beyond an examination of the vulnerability of only one aspect of the system (e.g., a fishing community's fishing activities) to a more holistic assessment (Allison and Ellis 2001). The scale of vulnerability analysis must also be appropriate to inform those who are vulnerable. National or global assessments, for example, might show that Bangladesh is more vulnerable than Nepal, which is more vulnerable than Greenland. These top-down approaches to vulnerability analysis provide little direct help to those at the local level. Given the importance of informal social networks for coping with shocks to a system and the tendency of bureaucracies to capture the lion's share of financial resources associated with disaster relief, engaging local communities in the assessment links theory and research with action.

Participatory vulnerability analysis is a systematic process of involving potentially affected communities and other stakeholders in an in-depth examination of conditions. Participatory vulnerability analysis provides a basis for formulating actions that support resilience-building. It can also be the basis for mitigation. The steps for the analysis include assessments of (1) exposure and sensitivities to determine past and current levels of risk, (2) historic strategies and constraints for coping with risks, (3) identification of possible future risks, and (4) development of plans for mitigating and or adapting to future risks (Smit and Wandel 2006). To be effective, the analysis should use multiple sources of knowledge (local and traditional knowledge,

modeling techniques, science-based analysis, remote sensing imagery) and address the multiple levels at which local, regional, and national decision makers might be engaged to reduce vulnerability. The objective is not to arrive at a single vulnerability score, but to build the resilience of the system to cope with anticipated and potentially surprising change. Addressing issues that reduce vulnerability and build resilience is usually incremental, so the process must track emerging conditions and make the necessary adjustments. The participatory approach can be helpful in energizing a community into action, but it must be approached with a grounded sense of realism that recognizes the day-to-day demands of local residents (see Chapter 4).

Summary

Well-being based on adequate livelihoods is essential to reduce vulnerabilities to the point that people can engage in long-term planning for ecosystem stewardship. Well-being depends on the acquisition of basic material needs including ecosystems services, as well as other social factors such as freedom of choice, equity, strong social relations, and pursuit of livelihoods. Once these basic human needs are met, people have greater flexibility to think creatively about options for ecosystem stewardship to meet the needs of future generations in a rapidly changing world. There has been a tendency however, for people to seek greater levels of consumption, once their basic needs are met, even though this leads to no measurable increase in happiness. Two important strategies to enhance sustainability are therefore to meet basic human needs and to shift focus from further increases in consumption to social–ecological stewardship, once the basic needs are met.

Social dimensions of vulnerability are intimately tied to elements of well-being, particularly to livelihoods; safety and security; and good social relations. Vulnerability can be assessed by identifying (1) the type and level of exposure of a system to hazards or stresses, (2) the system's sensitivity to these hazards, and (3) adaptive capacity and resilience of the system to make adjustments to minimize the impacts of hazards. Although many systems are experiencing increased stress from exogenous drivers like climate change and globalization of markets, the impacts of these stresses are strongly shaped by levels of well-being and associated endogenous stresses, such as poverty and conflict. Both exposure and sensitivity to stresses vary tremendously with time and place and among social groups. Reducing vulnerability therefore requires an understanding of spatial context and engagement of local stakeholders, particularly the disadvantaged, who might otherwise lack the power and resources to cope with change.

Resilience thinking adds to resource stewardship by addressing the capacity of social groups to cope with change, learn, adapt, and possibly to transform challenging circumstances into improved social–ecological situations.

Review Questions

1. What factors determine quality of life for an individual, household, or social group? Why is it important to understand people's quality of life and livelihood in a region if your goal is to foster ecosystem stewardship?
2. Describe how well-being influences exposure and sensitivity of a group to external hazards and stresses. Why is it often insufficient to simply provide food and shelter to people who have experienced an event such as a hurricane or drought if the goal of the aid is to reduce vulnerability?
3. What economic policies would be most likely to increase regional resilience to uncertain future changes in climate and a globalized economy? How might this be fostered?
4. How do conditions of rapid change enhance and or confound a household and a community's capacity to adapt?
5. What are some of the potential problems and practical applications of vulnerability and resilience frameworks?

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