Chapter 13
Emerging Concepts in Adaptive Management

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Introduction

Adaptive management is an elegant concept. Structure management interventions and policies as experiments, monitor feedback, and make necessary adjustments (Holling 1978, Walters 1986). Yet, the implementation of adaptive management has often been difficult, and the outcomes unclear. Lee (1993) offered a compelling account of the opportunities and challenges of adaptive management in the Columbia River Basin in the U.S. northwest in his book, 'Compass and Gyrscope'. He pointed not to matters of science as the primary stumbling block to adaptive management, but to a lack of enabling social and institutional conditions.

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McLain and Lee (1996) also documented the promise and pitfalls of scientific adaptive management. Their analysis highlighted adaptive management processes that did not effectively incorporate non-scientific forms of knowledge, recognize the social embeddedness of management decisions, engage with diverse stakeholders in cooperative ways, or orient adaptive management around more complex systems models. A special feature on adaptive management in Conservation Ecology (now Ecology and Society) in 1999 approached many of these same issues with a provocative question: "Adaptive management—scientifically sound, socially challenged?" Johnson's (1999) summary in this special feature outlined three main areas of concern: (1) the need to integrate stakeholders more effectively into adaptive management decision making; (2) the lack of institutional arrangements to support adaptive management; and (3) a failure to embrace management failure as a crucial part of learning for better outcomes. Two decades after Lee's (1993) book, many of these same constraints on adaptive management persist (Colfer 2005, Armitage et al. 2007, Westgate et al. 2013).

Examples of the successful application of adaptive management are few (Gunderson and Light 2006, Keith et al. 2011), and it remains more of an idealized concept than an empirically tested strategy to gain insights into the behavior of linked systems of people and nature (Lee 1999, Berkes et al. 2003). Westgate et al. (2013) documented the excess use of the term 'adaptive management' in a recent systematic literature review, and highlighted that only a small number of projects characterized as adaptive management effectively applied the concept to natural resource decision making (see also Gunderson and Light 2006). As Westgate et al. (2013) illustrate, further attention to the social context in which adaptive managers and scientists operate is crucial to achieving more credible and legitimate management outcomes.

We examine in this chapter six issues or concepts that emerge as central to ongoing efforts to advance the theory and practice of adaptive management of natural resources: (1) adopting a transdisciplinary perspective on adaptive management; (2) shifting from a natural resource management to social-ecological systems perspective; (3) situating adaptive management within a governance context; (4) surfacing the role of power in adaptive management processes; (5) engaging with knowledge co-production; and (6) exploring the role of adaptive management as a deliberative tool in support of social-ecological transformations.

Choices about what concepts to include here reflect our collective experiences and interest with adaptive management as it pertains to environmental change and governance. The concepts examined here further reflect recent directions in adap-

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tive management scholarship (broadly defined) and can help to build theory and situate the practice of natural resource management in a broader sustainability context. Others might choose to emphasize different concepts or issues, or depict the substantive concerns in alternative ways. In our view, however, the promise and elegance of adaptive management is more likely to emerge if practitioners and researchers situate their thinking in a transdisciplinary context of linked systems of people and nature, with reference to the issues of governance, power and knowledge, and as a strategy to encourage broader reflection on societies' interaction with natural resources. Consideration of these emergent concepts is likely to intensify the challenge of adaptive management. Yet without taking these issues into account, the promise of adaptive management is less likely to be realized.

A Transdisciplinary Turn in Adaptive Management

Science is based on mental models and social framings that influence the types of questions we ask, the data we collect and analyze, and ultimately our approaches to adaptive management (Peterson et al. 2003, Cumming and Collier 2005, Glaser 2006). Social framings of the natural world as predictable and controllable have been a mainstay of natural resource management for a century or more, and have served as the foundation for key management tools (e.g., maximum sustainable yield) (Gunderson et al. 1995). The emergence of adaptive management in recognition of ecological complexity and uncertainty was an important step forward in how managers framed natural resource management problems and solutions. However, first generation adaptive management has been driven largely by disciplinary science, and implemented in the context of segmented thinking and sector-based bureaucracies (Pinkerton 2007).

A transdisciplinary frame is crucial to meaningfully address complexity and uncertainty of natural resource management and foster a second generation of adaptive management. We follow Lang et al. (2012) in defining transdisciplinarity as an approach aimed to address the practical and conceptual dimensions of socially important issues, by integrating across diverse bodies of knowledge and explicitly involving stakeholders throughout a research and decision making process. In our view, a transdisciplinary frame for adaptive management should include: (1) defining research and management goals in terms of both socially and ecologically important issues—that is, recognizing people and the biosphere as a tightly coupled social-ecological system that is characterized by feedbacks across scales; (2) engaging in learning processes (formal and informal) through which knowledge about complex social-ecological systems is co-produced (e.g., science with the knowledge of resource users, researchers and practitioners); and (3) using that knowledge to transform societies' interactions with natural resources in ways that generate novel options for the maintenance of ecosystem services and human wellbeing.

Cooperation and reflexive practice (Ison et al. 2013) among multiple scientific domains and social groups is at the core of adaptive management, and those adaptive management processes that reflect the ideals of transdisciplinary practice are most likely to

yield outcomes that are legitimate and salient. Strategies to foster greater transdisciplinarity in adaptive management practice often emerge in the context of specific places and problems. These practices include innovative ways to utilize knowledge from a diverse range of actors, recognition that science is a crucial but bounded component of the sustainability challenge, and institutionalization of the learning processes that are at the core of efforts to deal with uncertainty and change.

Natural Resource Management in a Social-Ecological Systems Perspective

Social-ecological systems are defined as linked and co-evolutionary systems of society and nature (Berkes et al. 2003). A social-ecological system lens helps to situate adaptive management in the complexities of linked social and ecological systems, and is an important shift away from a focus solely on the management of individual natural resources (e.g., forest stand productivity). Acknowledging or anticipating feedbacks beyond an immediate resource system (e.g., forest stand, fishery) has emerged as a crucial component of managing for uncertainty (Gunderson et al. 1995). Choices about focal areas of concern and units of analysis place logistical constraints on the extent to which a social-ecological system lens might be applied in an adaptive management setting. However, using a social-ecological lens to frame adaptive management problems encourages multi-level analysis, incorporation of multiple social framings and ways of understanding social-ecological system problems, and therefore, recognition of the 'wicked' nature of many resource management problems (Rittel and Webber 1973, Allen et al. 2011). Specifically, thinking about adaptive management in terms of social-ecological systems helps to highlight a number of inherent features of linked systems of people and nature, including feedback processes among drivers of change across scales, and the nestedness of systems and social and ecological sub-systems (Table 13.1).

Orienting adaptive management theory and practice around the main features of social-ecological systems has a number of implications, such as: (1) reinforcing the philosophical foundations of adaptive management which are to embrace uncertainty and complexity (Holling 1978, Berkes 2003); (2) appreciating the resource context as a complex adaptive system that involves multi-directional flows between people and their environments (Kates et al. 2001, Berkes 2003, 2011, Mahon et al. 2008, Levin and Clark 2010); (3) recognizing connections among adaptive management of natural resources and the livelihood, food security and social wellbeing concerns of people and communities (Chuenpagdee et al. 2005, MEA 2005, Weeratunge et al. 2014); and (4) illustrating that decision making arrangements must reflect how the social domain (e.g., distribution of power) intersects with the ecological through multiple feedback processes (Berkes 2010, Nayak and Berkes 2010).

A social-ecological perspective compels adaptive management practitioners and researchers to look beyond theoretical, methodological and disciplinary boundaries to offer an overarching framework—an inclusive lens—to study social-ecological

Table 13.1 Implications of a social-ecological lens for adaptive management

Social- ecological system features	Description
Linkages	Emphasizes that the two parts (human systems and environmental/ biophysical systems) are only arbitrarily separable and equally important, and that they function as a coupled, interdependent, and co-evolutionary system (e.g., human actions affect biophysical systems, biophysical factors affect human well-being, and humans in turn respond to these factors) (Berkes 2011)
	Recognizes the role of humans in shaping ecosystem processes and dynamics thus valuing their capacity to influence and be influenced by ecological outcomes (Dale et al. 2000, Waltner-Toews and Kay 2005)
Feedback	Coupled systems exhibit nonlinear dynamics, thresholds, surprises, legacy effects and time lags (Liu et al. 2007)
	Extent and nature of coupling varies spatially, temporally and organizationally (Liu et al. 2007)
	Coupled systems have multiple drivers, an array of impacts, unpredictable ways in which drivers act, and multiple feedback interaction between human and biophysical systems (Nayak 2011)
	Interconnections and cross-scale dynamics among the social-ecological attributes become important factors that define the nature and extent of system complexity
Nestedness and sub-systems	Complex systems have a structural architecture characterized by hierarchical organization and interactions that take place between these nested systems (Simon 1962, Levin 1999)
	Focusing on sub-systems as distinct parts of the larger social-ecological system aids the development of understanding them, because they are valued as integral to each other, bound as a coupled system (Turner et al. 2003, Glaser 2006, Kotchen and Young 2007)
Scale	Observed dynamics and behavior of ecosystems and social-ecological systems are the result of the interplay of structures and processes that vary spatially and temporally (Levin 1999, Gunderson and Holling 2002, Cash et al. 2006)
	Allows us to think about complex multi-scale processes within the social-ecological system and determine appropriate scales of intervention for adaptive management

systems. Finally, by bringing the social context into a conventionally resource-focused approach, a social-ecological system lens helps to highlight the conflicts and distributive justice challenges of adaptive management, along with impacts on livelihoods and potential for inequity and problems of participation in decision-making processes (Berkes et al. 2006, Liu et al. 2007, Nayak and Berkes 2014). We address several of these emergent challenges in subsequent sections below.

Situating Adaptive Management in a Governance Context

Management and governance are neither synonymous, nor mutually exclusive. Management typically involves the operational decisions taken to achieve specific outcomes (e.g., increases in yield of a desired resource stock). Governance often refers to the broader processes and institutions through which societies make decisions that affect the environment (see Oakerson 1992). Biermann et al. (2009) define governance as "the interrelated and increasingly integrated system of formal and informal rules, rule-making systems, and actor-networks at all levels of human society (from local to global) that are set up to steer societies toward preventing, mitigating, and adapting to global and local environmental change." In this context, institutions are the formal and informal "working rules" and associated decisions (e.g., for monitoring and enforcement) that mediate interactions among people and their environments (Ostrom 1990). We use governance to refer to both an analytical lens to examine the broader set of rules and actor networks within which adaptive management actions and decisions take place, as well as specific arrangements for adaptive decision making about natural resources among government agencies, industry and resource user groups (see Armitage et al. 2012).

Gunderson and Light (2006) suggested that thinking in terms of adaptive governance can help "increase responsiveness and generate more diverse and versatile competencies that create options for the future and develop the adaptive capacity to improvise and adjust to recurring crises." This makes good sense given the social-ecological complexities of most natural resource management settings. However, working towards such a goal inevitably requires managers and other actors in an adaptive management process to consider more thoroughly the social and institutional constraints within which they operate, reflect on levels of power and authority among the actors involved in adaptive management, bridge diverse knowledge systems, and build adaptive capacity to support more fundamental transformations in how societies interact with natural resources. As Gunderson and Light (2006) noted, "adaptive governance deals with the complex human interactions that have been obstacles to the implementation of adaptive management," which include institutional constraints and contested and divergent values, goals, and objectives between actors.

Situating adaptive management in a governance context generates a number of useful insights for managers and resource users (Box 1). For example, government agencies with the mandate for adaptive management cannot be the only source of decision making, although they have a crucial role to play in that regard. As more actors (industry, user groups, civil society organizations) enter the adaptive management arena, different types and sources of knowledge will gain legitimacy. Indeed, our current understanding of social-ecological systems is incomplete and multiple types of knowledge are necessary to inform decisions (Brunner et al. 2005, Folke et al. 2005). A governance perspective (see Garmestani et al. 2009) helps managers to recognize the legitimacy of diverse and sometimes peripheral actors with new

roles in resource and ecosystem management, and helps convey a "multi-objective reality when handling conflicts among diverse stakeholders" (Folke et al. 2005).

Box 1: Implications of a Governance Lens for Scientists and Managers

Consider emergent actors with new roles in resource and ecosystem management
State agencies are no longer the main actor or sole source of decision-making. Hybrid arrangements involving state and non-state actors have emerged, offering alternative and promising models, but have also created new challenges associated with accountability, legitimacy and scale.

Recognize that adaptive management occurs in contested and power-laden social contexts
Power underlies all adaptive management processes, and influences how trade-offs between multiple, competing objectives are made. Acknowledging and understanding the role of power encourages reflection on and recognition of the contested and divergent assumptions, values and goals amongst actors involved in decision-making.

Appreciate the need for engaging and bridging diverse knowledge systems for learning
Scientific knowledge of complex social-ecological systems is often incomplete, creating pitfalls when relying on it as the exclusive source of information for decision-making. Knowledge that is co-produced by bridging diverse sources and types is typically better suited for navigating complexity and uncertainty (Berkes 2009).

Embrace the challenge of adaptation
Adaptation to maintain or preserve existing features of social-ecological systems is necessary to address environmental change. Capacity to meet the challenge of adaptation is crucial, as is the need to recognize maladaptive practices and consider more fundamental system transformations. In light of ongoing processes of change in social-ecological systems, expectations of adaptive management need to be continually refined.

A governance lens may also encourage adaptive managers to reflect on the multiple domains (social, economic, ecological) in which their problems are nested (see Westley 2002, Garmestani et al. 2009). In other words, a governance perspective can facilitate an integrative or social-ecological view (as above), rather than a traditional regulatory or sectoral view. Similarly, a governance lens highlights the social structures and processes (i.e., networks) that link individuals, organizations, agencies, and institutions in a multi-level world (Olsson et al. 2004). Since actors interact vertically and horizontally within such networks, strong network arrangements

are hypothesized to enhance the capacity for adaptive management by facilitating processes of learning and building legitimacy of decision outcomes (Armitage et al. 2012). However, such networked and/or multi-level arrangements also have disadvantages. They may require more time for decisions to be made, and exacerbate political, economic or livelihood conflict if not carefully facilitated. A governance lens thus highlights the need to strengthen capacity to manage adaptively across scales, but also to recognize that any management process is bounded by broader political, economic and institutional conditions that will ultimately define transitions towards sustainability.

Surfacing Power in Adaptive Management

The emergence of hybrid governance arrangements emphasizes a transition from the single state/agency actors in resolving management challenges, to network strategies involving combinations of actors from states, the private sector, and civil society (Lemos and Agrawal 2006). As the preceding discussion on governance highlights, adaptive managers are increasingly engaged with a broad array of actors outside formal (i.e., government) spheres that seek to influence the management of natural resources (Ansell and Gash 2008, Ali-Khan and Mulvihill 2008). Any decision regarding natural resources is inherently influenced by social relations of power (Bryant 1998, Brechin et al. 2003, Ansell and Gash 2008). Adaptive management processes are required to more effectively consider questions about actor inclusion (i.e., who participates in hypothesis generation, knowledge production, data analysis?), as well as questions about influence, the legitimacy of actor participation, and the distribution of power among actors (i.e., how effectively do different actors participate in various phases of adaptive management?).

We define power here as the application of action, knowledge and resources to resolve problems and further interests (Adger et al. 2005, Raik et al. 2008), and we identify four related arenas through which to consider power in adaptive management: (1) decision-making; (2) authority and control; (3) action; and (4) knowledge. These categories are not exclusive, and some social actors may span multiple categories (Table 13.2).

In adaptive management, a failure to address or consider differences in power among actors can have far-reaching implications for the legitimacy of decisions about natural resources (Borrini-Feyerabend et al. 2007, Larson and Soto 2008, Biermann and Gupta 2011). The differences in power among actors may be linked to capacity limitations (e.g., financial, technical), which may contribute to uneven representation in terms of the issues addressed and the interests considered (e.g., Stringer et al. 2006, Kallis et al. 2009). However, structurally embedded constraints related to institutions (e.g., rights, rules) and the marginalization of certain groups are more likely to be a foundational reason for uneven distribution of power among participants in an adaptive management process. In either case, unequal distributions

Table 13.2 Arenas of power in adaptive management

Arenas of power	Description	Roles and responsibilities	Examples	References
Decision-making	The power to meaningfully influence decisions	Participant, negotiator, discussant, persuader, advisor, consultant, communicator	Engagement of actors (e.g., tourism, government, NGO, community etc.) via a multi-stakeholder Management Advisory Board in Bunaken National Park, Indonesia (Erdman et al. 2004)	Mannigel 2008, Ferse et al. 2010
Authority and control	The power to coerce or constrain human action	Rule maker, decision maker, enforcement	Devolution of Brazil's water sector to local multi-stakeholder river basin councils generates varied levels of authority across states (Engle et al. 2011). Ongoing decentralization reforms across sub-Saharan Africa are transferring decision-making powers to local governments and organizations in the context of natural resource management (Ribot 2003)	Agrawal and Ribot 1999, Njaya et al. 2011, Campbell et al. 2013
Action	The power to execute	Implementer, monitor, adjudicator	Local enforcers (*kewang*) and traditional local leaders play a vital role in the functioning of customary *sasi* marine management systems in eastern Indonesia (Harkes 1998, Satria and Adhuri 2010)	Mappatoba 2004
Knowledge	The power to gather, learn, possess, and exclude knowledge	Knowledge holder, knowledge broker, knowledge (co)producer	Multi-stakeholder riparian management in the Sprucedale National Forest, southwestern USA results in competing discourses where differential power amongst actors is used to select knowledge sources and influence decision making (Arnold et al. 2012)	Natcher 2005, Nadasdy 2007, McGregor 2012

of power may lead to poor social, and ultimately ecological, outcomes (Lebel et al. 2005, Nadasdy 2007).

Explicit recognition of structural and agent-based dimensions of power and their interactions (see Raik et al. 2008) can prove crucial to successful adaptive management, particularly given the increasingly hybrid, networked and multi-level decision making arenas within which adaptive managers are situated. The sharing of

authority and control among diverse actors is increasingly encouraged as an approach to management of a wide range of natural resources (Borrini-Feyerabend et al. 2007), and manifests in many ways, such as in the form of government-indigenous partnerships, community agreements on conservation, or collaborative management arrangements more generally (Press et al. 1995, Mappatoba 2004, Fox et al. 2008). In these contexts, the focus is less on active adaptive management, and more on the social process of learning by doing, monitoring and collaborative decision making in response to the uneven distribution of power among communities, conservation organizations and government agencies (Salafsky et al. 2001).

Knowledge Co-production in Principle and Practice

Knowledge systems are defined as interconnected symbols that create meaning about reality that humans co-construct and adapt over time (Dryzek 2005, Reid et al. 2006). Knowledge systems thus reflect a knowledge-practice-belief complex (Berkes 2012), where meaning emerges from actors co-constructing symbols, artifacts, competencies, and norms to enact 'what we know' and 'how we know it' (Midgley 2000). It is crucial for actors in adaptive management to recognize that knowledge is as much a social process (i.e., governance) as it is a set of outcomes (e.g., management plans).

Undertaking how to bridge knowledge systems in adaptive management is an area still in need of significant effort. Where efforts to bridge knowledge systems have been meaningfully attempted, they have often occurred in the context of collaborative and deliberative processes (Berkes and Davidson-Hunt 2008). Knowledge co-production can be defined as "the collaborative process of bringing a plurality of knowledge sources and types together to address a defined problem and build an integrated or systems-oriented understanding of that problem" (Armitage et al. 2011). Such processes encourage managers and other actors to: (1) examine different narratives of (or stories about) environmental change and uncertainty (Batterbury 1997, Dietz et al. 2003); (2) enhance their overall capacity to understand and accept uncertainty (Reidlinger and Berkes 2001); (3) allow actors to formulate shared visions to guide decision making (Peterson 2007); and (4) encourage a shift away from knowledge integration towards knowledge exchange (Fazey et al. 2013). A knowledge co-production approach seeks to maintain the integrity of participating knowledge systems and knowledge holders, while creating space for the development of novel and hybrid understandings needed to learn through uncertainty. This is a hallmark of adaptive management.

Evidence shows that bridging diverse knowledge systems improves the overall understanding of environmental phenomena among different groups (Reidlinger and Berkes 2001, Reid et al. 2006), and enhances the perceived salience, credibility and legitimacy of adaptive management (Cash et al. 2003, Mitchell et al. 2006, Reid et al. 2006). Knowledge of different types and from different sources (scientific, local, traditional) can improve the quality of decisions (Reid et al. 2006, Reed et al.

2013). For example, Laidler (2006) illustrates how Inuit and scientific knowledge holders use very different processes to understand and act upon changes in Arctic sea ice. Scientists use satellite imagery or local instruments to measure and verify changes with the aid of statistical modeling, whereas Inuit use their observations gained during hunting or other land-based practices and verify changes by sharing and discussing their experiences with other community members (Laidler 2006, Laidler et al. 2010). Hybrid knowledge, emerging from the contributions of different knowledge systems (e.g., western/scientific, local and indigenous), can create novel understandings of environment and natural resource management that are different from what either knowledge system could support on its own (Reidlinger and Berkes 2001, Armitage et al. 2011).

Knowledge emerging from artistic processes may also play an important role to bridge knowledge systems and thus can contribute to successful adaptive management (see Box 2). Art and artistic processes reflect a particular type of knowledge system, and they can also help to bridge different actors and enable reflection on how different knowledge systems can be used to make sense of environmental change and uncertainty (Vancouver Art Gallery 2006, Zurba and Berkes 2014). Further, art and artistic processes can help groups of individuals envision future changes at a number of scales—local to global (Elgin 2002, Davies and Sarpong 2013). Exploration of the role of art and artistic processes in adaptive management is warranted, and may include many different mediums (e.g., storytelling, digital media). In some cases, those engaged in artistic endeavors may be key resource users with direct connection to the decisions being made about resource systems. In other cases, art and artistic processes may be produced by independent actors but serve as a form of 'boundary object' around which dialogue and learning take place.

Box 2. A Role for Artistic Process in Adaptive Management?

Art and artistic processes can contribute to bridge different knowledge systems and may contribute in innovative ways to adaptive management. Artistic processes are similar to scenario planning, which is a reflective and forward-looking means of bridging knowledge systems in the adaptive management approach (Bennett and Zurek 2006). Artistic processes and mediums, such as music, theater and oral-history, offer a safe and culturally-embedded means of exploring and reflecting upon the human dimension of environmental change (Zurba and Berkes 2014). Creating space for these artistic forms in a governance setting is one way to demonstrate respect for diverse cultures, while providing opportunities for meaningful deliberation on key challenges. Take for example the Arctic Gnomes at Eden instillation project by Bullet Creative. This piece uses interactive instillation art to help individuals conceptualize changes in Arctic Sea ice (http://www.capefarewell.com/news/events/687-arctic-gnomes-at-eden.html). Shifting mental models about the way the world works is central to the process of adaptive management. Art and artistic process can enhance understanding of our own mental models and those of others, and may emerge as a key piece of the adaptive management puzzle.

Beyond the pragmatic benefits of bridging knowledge systems the inclusion of diverse knowledge systems in adaptive management has substantive political and ethical benefits (Bohensky and Maru 2011). And in contexts where uneven power distribution has undermined local and indigenous input in decision-making this need may be acute (see Tuhiwai Smith 1999, Mascarenhas 2007).

Adaptive Management as An Arena for Deliberative Transformations

Adaptive managers must define meaningful goals to achieve specific resource targets (e.g., annual allowable cut) or desired social and ecological outcomes (e.g., greater biodiversity, enhanced human wellbeing). Trade-offs among social and ecological outcomes or targets will incur additional uncertainties, and will generate conflict among managers, resources users and other civil society actors. In and of itself, the challenge of adaptive management is daunting. However, since adaptive management of natural resources is situated in a wider social-ecological system context (e.g., forest stand management in a wider regional planning process), defining goals and targets must also connect with broader debates about trajectories of desired change—not just natural resource management outcomes. A core tension in such debates often centers on the decision to adaptively manage natural resources in the context of uncertainty as opposed to fostering more deliberative transformations in situations where adaptive management may contribute to unsustainability in the first place.

Transformation refers to a fundamental shift in ecological, economic and social conditions when existing system trajectories (ecological, social, economic) are untenable (Walker et al. 2004, Chapin et al. 2009, Folke et al. 2010). With reference to adaptive management, we are interested primarily in the notion of deliberative or directional transformations, which are carried out with the intention of achieving particular (positive) outcomes (see O'Brien 2012). Transformations are different from adaptations because they typically challenge rather than seek adjustments to or maintain the current system or the *status quo* (Pelling 2011, O'Brien 2012). A key feature of deliberative transformations is recognition that fundamental shifts in some elements of a system or sub-system are needed to achieve desirable futures (see Miller et al. 2010).

Olsson et al. (2006) outlined a three-phase heuristic for thinking about transformations: (1) preparing for change; (2) navigating the transition from one regime to another; and (3) building resilience in the new regime. Strategies to operationalize such heuristics take us into the realm of adaptive management and governance. For example, preparation for change may occur through co-production of knowledge amongst diverse actors, which can help to identify undesirable or untenable regimes, possible alternatives, thresholds, and barriers to change (Hahn et al. 2006, Pahl-Wostl 2009, Chapin et al. 2009). Shadow or informal networks may be particularly important as these networks can facilitate experimentation and the identifica-

tion of new approaches or governance arrangements (Olsson et al. 2006, Sendzimir et al. 2007, Moore and Westley 2011). By recognizing the broader governance context, adaptive managers may be better able to engage with some of these actors and processes that take place outside of formal adaptive management settings.

Navigating transitions is a highly unpredictable process, requiring significant flexibility and improvisation—key tenants of adaptive management. Transformative change implies significant uncertainty, and adaptive management provides an important strategy with which to monitor and assess specific interventions against long-term system goals. Adaptive management is thus a concrete way to encourage certain types of change in a deliberative manner. In the absence of careful thought about the broader context in which adaptive management occurs, there is a danger that unsustainable trajectories may be exacerbated or continued. In an effort to support the knowledge base required for deliberate transformations, however, adaptive management provides a setting to assess key variables (ecological and social) that contribute to social-ecological transformation.

Conclusions

Several decades of experience point to deeply embedded social and institutional constraints on the processes of adaptive management and resulting outcomes. We have outlined several concepts that are rooted in social and institutional processes and conditions that have emerged as fundamental to the adaptive management of natural resources (Table 13.3). These concepts provide an entrée to understand some of the pitfalls, but also the promises, of adaptive management, and they provide a frame through which to consider the theory and practice of adaptive management. Despite the challenges, adaptive management remains a set of concepts, principles and practices with significant potential to help societies navigate towards sustainability in an uncertain world (see Allen et al. 2011).

Table 13.3 Emerging concepts and the implications for adaptive management

Concept	Implication
Trans-disciplinarity	Supports adaptive managers and scientists to engage with alternative methodological approaches and knowledge systems
	Inherent uncertainty and unpredictability requires novel ways to understand social-ecological systems that are not bound by disciplinary traditions
	Encourages development of different hypotheses about, and analyses of, complex problems to better inform decisions and management interventions
Social-ecological systems approach	Situates adaptive management in the complexities of linked systems of people and nature and encourages consideration of their inherent features
	Challenges linear thinking, sectoral approaches, and the neglect of social drivers (positive, negative) of change and their feedbacks
	Encourages multiple-level analysis to determine appropriate scales of intervention for adaptive management, as well as linkages among natural resources, livelihoods, food security, social wellbeing, justice and power
	Embracing uncertainty and complexity may lead to fewer or less detrimental unintended consequences (i.e., surprises)
Governance	Encourages managers and scientists to consider more systematically the larger institutional frameworks and networks within which they operate, and linking a focus on outcome oriented operational decisions with societal processes and institutions that influence decisions about natural resources
	Helps adaptive management actors to recognize the institutions (rights, rules, norms), and their interplay across scales, at the core of decision-making
	Expands thinking about who is involved in and influences management processes (i.e., actors who may not be included in formal arrangements can have an important influence on adaptive management or perceptions of outcomes)
	Considers emergent actors and novel hybrid arrangements while situating adaptive management within a context of complex human interactions influenced by diverse values, goals and objectives
Knowledge co-production	Facilitates recognition that multiple types of knowledge are necessary to inform decisions
	Highlights availability of diverse strategies and processes to link different types and sources of knowledge (i.e., bridge knowledge systems)
	Co-producing knowledge about uncertain conditions can lead to robust understandings of the environment and for adaptive management, and novel hypotheses to be tested
Power	Encourages greater contextualization about natural resource ownership and control, and leads to enhanced credibility and legitimacy of decision outcomes
	Recognizes social power as a key driver in success and failure of adaptive management
	Facilitates increased attention to how power is distributed and its linkages to capacity and representation in adaptive management

Table 13.3 (continued)

Concept	Implication
Transformation	Expands perspectives and approaches of managers and scientists regarding pervasive problems contributing to the unsustainability of social-ecological systems
	Challenges core assumptions about the goal(s) of adaptive management by encouraging reflection on broader system trajectories and outcomes
	Highlights the potential role of adaptive management in fostering deliberative transformation through uncertainty.

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