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Adaptive Water Governance: Integrating the Human Dimensions into Water Resource Governance

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Abstract: The command-and-control paradigm of water resource management that dominated 20th century water policy has resulted in vulnerabilities due to its inadequate consideration of the human dimensions as well as its failure to prioritize the need for learning and adapting to change and uncertainties. In response to these shortfalls, recent years have seen the emergence of alternative water policy frameworks, notably integrated water resource management (IWRM) and adaptive management. However, while IWRM broadens the planning goals and scope of water resource governance through integration and coordination across scales and sectors, it does not adequately emphasize learning to deal with uncertainty. On the other hand, adaptive management emphasizes the need to prioritize learning to deal with uncertainty in resource management through monitoring and experimentation, but places less emphasis on the human dimensions required for its successful implementation. This paper discusses adaptive water governance – collaborative, flexible, and learning-based institutions that connect state and non-state actors across multiple levels for ecosystem-based management of land and water resources – as a promising institutional mechanism for integrating the human dimensions into water resource governance while building the capacity of water resource systems to learn and adapt to change. The paper highlights four attributes of adaptive water governance: (1) reintegrating humans into nature; (2) integrating diverse sources and types of knowledge; (3) promoting adaptive and integrative management goals; and (4) using polycentric institutions and analytic deliberation processes. Through these mechanisms, adaptive governance can contribute to sustainability, good governance, conflict management, and social-ecological resilience in water resource systems.

Keywords: *adaptive management, climate change, resilience, social-ecological systems, vulnerability, water policy*

In recent decades, the uncertainties and complexity associated with water resource systems have been gaining widespread recognition (Pahl-Wostl et al. 2007; Huitema et al. 2009; Akamani and Wilson 2011). The anticipated impacts of climate change, coupled with the interactions among the multiple social, ecological, and technological components of water resource systems add to this complexity (Pahl-Wost 2007b; Pahl-Wostl et al. 2009). In this context, the concepts of resilience and vulnerability are increasingly receiving attention in efforts to enhance the sustainable governance of water resources in the face of uncertainties from climate change and other drivers of change. Resilience refers to the capacity of a system to absorb disturbances while maintaining its structures, processes, and feedbacks (Berkes 2007). Vulnerability, on the other hand, is the degree of susceptibility of a system to harm from exposure to hazards (Turner et al. 2003). The conventional command-and-control water management paradigm that dominated much of 20th century water policy was premised on a belief in the ability to control and predict water resource systems emphasis on the pursuit of economic efficiency, reliance on positivist science, dominance of rational-comprehensive planning processes, and top-down institutional mechanisms (Pahl-Wostl et al. 2007; Raadgever et al. 2008; Molle 2009). Two shortfalls associated with this paradigm are the neglect of the human dimensions in water management (Floress et al. 2015), and the lack of emphasis on the need for learning and adaptation (Pahl-Wostl 2007b). These shortfalls have led to the erosion of resilience and increased vulnerability in water resource systems (Pahl-

Wostl 2007a; Sendzimir et al. 2008).

Through recent transitions in the governance of water resources toward integrated water resource management (IWRM) and adaptive management, the shortfalls in the conventional command-and-control paradigm of water resource management are being addressed in diverse ways. The concept of IWRM broadens the planning goals and scope of water resource governance through integration and coordination across scales and sectors, but does not adequately emphasize learning to deal with uncertainty (Biswas 2004; Medema et al. 2008; Gain et al. 2013). The concept of adaptive management also emphasizes the need to prioritize learning to deal with uncertainty in resource management through monitoring and experimentation, but emphasizes less on the human dimensions (e.g., stakeholder values, interests, and decision-making processes) required for its successful implementation (McLain and Lee 1996; Walters 2007). Thus, ongoing efforts aimed at integrating the human dimensions into water management processes and goals have not adequately accounted for the need to adapt to uncertainties, whereas those efforts focused on reducing uncertainties have not given adequate consideration to the human dimensions. Through the reconciliation of adaptive management and integrated resource management, the emerging literature on adaptive governance of social-ecological systems offers promise for integrating the human dimensions into water resource management as well as preparing linked social and ecological systems to learn and adapt to gradual and episodic changes. The pursuit of adaptive governance could contribute to enhancing good governance, conflict management, and building social-ecological resilience for sustainable water resource management (Dietz et al. 2003; Folke et al. 2005; Akamani and Wilson 2011). Yet, these potentials remain largely unexplored. Existing knowledge gaps in the adaptive governance literature include poor understanding of the conditions and processes for the emergence of adaptive governance regimes (Österblom and Folke 2013) and inadequate understanding of factors influencing success and failures in such regimes (Karpouzoglou et al. 2016). Methodological tools for assessing the outcomes of adaptive governance across multiple scales also remain largely undeveloped, although progress is being made in this direction (e.g., Schultz et al. 2015; Morris and de Loe 2016).

In this paper, I examine the prospects of adaptive governance as a conceptual foundation for adaptive and integrated water resource management, thereby providing a framework for integrating the human dimensions into the governance of water resources while simultaneously dealing with uncertainties. According to Jacobson and McDuff (1998, 265), the human dimensions encompasses "the beliefs, attitudes, values, behaviors, and socioeconomic, demographic, and organizational characteristics of the stakeholders involved in natural resource conservation issues." As such, the field of human dimensions borrows from a wide range of disciplines in the social sciences and humanities, including philosophy, economics, political science, anthropology, sociology, and social psychology to understand, explain, predict, and guide policies on human-environment interactions. The integration of the human dimensions in natural resource management is increasingly seen as an essential part of efforts aimed at promoting sustainable human-environment interactions (Endter-Wada et al. 1998; Mascia et al. 2003; Manfredo et al. 2014). For the purposes of this paper, I refer to the human dimensions as the social considerations in the assumptions, goals, knowledge, and institutional structures and processes that inform resource management. The next section of the paper presents an overview of transitions in the water governance literature by discussing the concepts of IWRM and adaptive management. Next, adaptive governance and its potential contributions to the human dimensions of water resources governance under dynamic conditions will be discussed. Concluding remarks will then be offered in the final section of the paper.

Evolving Approaches to Water Resource Governance

Integrated Water Resource Management (IWRM)

The concept of IWRM is one of the most widely discussed water policy frameworks in recent decades. The need for IWRM is born out of realization of the increasing interconnectedness between the water sector and other development

sectors such as agriculture, energy, industry, transportation, health, environment, and rural development across multiple scales from the local to the international (Biswas 2004). The complexity of these interactions is further compounded by the onslaught of economic and cultural globalization, climate change, and other global processes. Within this context, managing the different aspects of water resources in isolation from one another threatens long term sustainability (Engle et al. 2011). Realization of water policy goals will require the explicit and simultaneous consideration of potential trade-offs between the water sector and related sectors at various spatial and temporal scales (Biswas 2004; Pahl-Wostl 2007a; Pahl-Wostl et al. 2007). The concept of IWRM (Biswas 2004; Molle 2009) emerged in the 1990s to address these management challenges.

In an oft-quoted definition, the Global Water Partnership (GWP 2000, 22) defines IWRM as "a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems." More recently, Gain et al. (2013, 14) define IWRM as "an integrated form of sustainably managing water and associated resources at the river basin scale involving specific governance forms that guarantee multi-stakeholder participation, equitable access and efficient use of water resources." IWRM is a holistic resource management approach that primarily aims at promoting the coordinated and integrated management of land and water resources to enhance water resource sustainability (Medema et al. 2008). Through this holistic approach, IWRM has the potential to overcome the shortfalls associated with the conventional approach to managing water resources in isolation from other sectors (Blomquist and Schlager 2005; Pahl-Wostl et al. 2007). IWRM represents an important step toward the integration of the human dimensions into water resource governance through its emphasis on the integration of multiple disciplinary and stakeholder perspectives across multiple scales, as well as its emphasis on fairness, participation, and decentralized governance systems (Medema et al. 2008; Engle et al. 2011; Plummer et al. 2011; Gain et al. 2013).

In spite of its promise, the concept of IWRM has seen limited success in practical implementation (Blomquist and Schlager 2005). Medema et al. (2008) have identified three conditions for the successful implementation of IWRM programs: availability of enabling legislation and policy environment; appropriate institutional frameworks; and availability of instruments for assessments, as well as gathering of data and information. However, these ideal conditions rarely exist. The implementation of IWRM programs is often constrained by a range of challenges, including the lack of clarity and consensus in the meaning of the concept, capacity and institutional constraints in the implementation of integrated approaches across multiple sectors, and the lack of appropriate indicators for assessing success in IWRM programs (Biswas 2004; Medema et al. 2008). Using the case of a small watershed in Southern California, Blomquist and Schlager (2005) highlight the political challenges entailed in defining the boundaries of watersheds, choosing appropriate decision-making structures, and enhancing accountability in IWRM. Importantly, IWRM has not adequately addressed the uncertainties entailed in the management of water resource systems in the face of climate change impacts and other drivers of change (Pahl-Wostl et al. 2007; Engle et al. 2011; Gain et al. 2013).

Adaptive Management

Since the 1970s, adaptive management has been receiving attention as an approach for dealing with the complexity and uncertainties entailed in the resource management process (Holling 1978; Walters 1986). The concept has been particularly embraced in the field of water resource management (Pahl-Wostl et al. 2007; Huitema et al. 2009; Engle et al. 2011). Adaptive management is a resource management approach that is based on the assumption that resource management occurs in the face of incomplete knowledge and unpredictable social and ecological interactions (Ringold et al. 1996; Lee 1999; Walters 2007). As a consequence, adaptive management aims at enhancing the resilience and flexibility of management systems to cope with uncertainty (Allen et al. 2011; Allen and Gunderson 2011). Pahl-Wostl (2007a, 567) defines adaptive management as "a systematic process

for continually improving management policies and practices by learning from the outcomes of implemented management strategies." While definitions vary, adaptive management generally refers to a structured process of learning by doing in the face of uncertainty (Walters 1997). Structured decision making provides a systematic and transparent process for identifying and evaluating policy alternatives in the adaptive management process (Allen et al. 2011). However, not all forms of adaptive management follow such processes.

Based on Walters and Holling (1990), Allan and Curtis (2005) identify three types of adaptive management: evolutionary; passive; and active adaptive management. Evolutionary adaptive management occurs in the form of trial and error learning, i.e. random experience. For instance, the adaptive component of locally evolved resource management systems that occur via experiential learning is gaining recognition (Berkes et al. 2000; Olsson and Folke 2001). Passive adaptive management entails the implementation of an informed policy option based on the best available data, followed by monitoring of the implementation process (Allan and Curtis 2005; Gregory et al. 2006). Passive adaptive is relatively simple and less expensive due to its non-experimental nature (Medema et al. 2008). As such, it is largely favored by government representatives in the policy process (Gregory et al. 2006). Active adaptive management facilitates learning by treating the resource management process as an experiment to test competing hypotheses, as well as emphasizing monitoring and integration of new knowledge into subsequent management actions (Gregory et al. 2006; Allen and Gunderson 2011; Benson and Garmestani 2011). Active adaptive management bridges the gap between science and policy through its experimental resource management approach (Medema et al. 2008; Allen et al. 2011; Benson and Garmestani 2011; Smith 2011). While active adaptive management is generally considered the most superior form of adaptive management from the standpoint of enhancing learning (Benson and Garmestani 2011), there is little evidence of its successful implementation (Gregory et al. 2006; Allen and Gunderson 2011).

The challenges in the conceptualization and implementation of adaptive management processes have received considerable attention in the literature. Walters (1997) discusses four impediments to adaptive management of riparian and coastal ecosystems: technical difficulties in the development of accurate models representing complex social-ecological relationships; perceived risks and costs associated with large scale adaptive management experiments; opposition to experimentation by vested interests; and conflicts in values and interests among stakeholders in the adaptive management process. In his assessment of the Everglades of Florida, Gunderson (1999) also cautioned that adaptive management cannot succeed where there is a loss of resilience in the ecological system and/or a lack of flexibility in the social system. The literature on land and water resources increasingly highlights the social and institutional nature of barriers to adaptive management success, including the absence of enabling regulatory and policy environments, lack of leadership, declining resources and capacity for monitoring and experimentation, reluctance of policy makers to embrace the uncertainty assumptions of adaptive management, lack of adequate engagement of stakeholders, neglect of nonscientific forms of knowledge, and inadequate consideration of the broad range of social values in adaptive management processes (McLain and Lee 1996; Stankey et al. 2003; Walters 2007; Allen and Gunderson 2011). In view of these insights, it has been argued that successful adaptive management will require institutional mechanisms that adequately promote stakeholder involvement, as well as integration of diverse values and knowledge systems (McLain and Lee 1996; Folke et al. 2002). This call for the integration of the human dimensions into adaptive management of water resources requires an adaptive governance approach (Folke 2006; Gunderson and Light 2006; Walker 2012; Aytur et al. 2015; Morris and de Loe 2016).

Adaptive Water Governance

Adaptive governance of social-ecological systems (Dietz et al. 2003; Folke et al. 2005) is a promising alternative to the command-and-control paradigm of water resource management, and it holds promise as the foundation for adaptive and integrated management of water and other

natural resources. Adaptive governance addresses the social and institutional context that enables adaptive ecosystem-based management (Folke et al. 2005; Folke 2006). Österblom and Folke (2013) contend that adaptive governance is suitable for dealing with change and complexity in a context characterized by diverse actors with differences in values, interests, and power that give rise to conflicts. As such, adaptive governance has the potential to address the dual challenge of integrating social considerations into the resource management process, as well as dealing with uncertainties in complex social-ecological systems. Adaptive governance is a collaborative, flexible, learning-based approach to ecosystem management that relies on a diverse network of institutions and organizations across multiple levels from the local to the international (Hughes et al. 2005; Olsson et al. 2006). The adaptive governance framework also provides a medium for linking science and decision-making in an ongoing process of dealing with change (Gunderson and Light 2006). Adaptive governance is closely related to adaptive management (Holling 1978; Allen et al. 2011), as well as other mechanisms for governing common pool resources, such as co-management (Berkes 2009) and adaptive co-management (Olsson et al. 2004; Plummer 2009). However, adaptive governance is particularly suited for situations involving abrupt and transformational change in social-ecological systems (Olsson et al. 2006; Walker 2012). Transformational changes entail the crossing of critical thresholds, resulting in a shift from one regime to another (Folke et al. 2010; Walker 2012). In such situations, adaptive management and adaptive co-management have limited applicability, as they mainly address the capacity to deal with change while staying within an existing social-ecological regime (Olsson et al. 2014).

Transformation toward adaptive governance for ecosystem-based resource management is influenced by many factors, including the availability of enabling legislation, presence of economic and non-economic incentives, bridging organizations, windows of opportunity, and leadership (Folke 2007; Olsson et al. 2008; Folke et al. 2010; Gelcich et al. 2010; Österblom and Folke 2013). While the burgeoning literature on adaptive governance is quite disparate, key attributes of adaptive governance include the following: embracing complexity and resilience through recognition of the interdependence between social and ecological systems; promoting adaptive, integrated resource management goals; utilizing diverse sources of knowledge; and relying on polycentric institutional structures and analytic deliberation processes for managing conflicts (Dietz et al. 2003; Hughes et al. 2005; Gunderson and Light 2006; Nelson et al. 2008). These attributes do not exist in isolation but seem to operate as interconnected aspects of adaptive water governance as a resource regime. The ensuing section discusses how these four attributes of adaptive governance I identify in the existing literature can contribute to integrating the human dimensions into water resource management assumptions, goals, knowledge systems, and institutions while preparing the coupled social-ecological system to deal with uncertainties.

Reintegrating Humans into Nature

At the philosophical level, conventional resource management has been critiqued for its flawed assumption of nature-culture dichotomy whereby social and ecological systems are treated as separate from each other (Folke et al. 2002; Berkes 2004). Alberti et al. (2003, 1170) have noted that "Despite dominating Earth's ecosystems, humans remain conspicuously excluded as subjects of much ecological thinking and experimentation. Traditional ecological research investigates ecosystems in terms of biophysical, ecological, and evolutionary processes unaffected by human influences." Similarly, social science fields, such as common pool resources research, have typically focused on the social system without adequate consideration of the ecological system on which the social system depends (Hughes et al. 2005). The roots of the separation of social systems from the natural world have been traced to multiple sources, notably the balance of nature paradigm (Cole and Yung 2010), the Judeo-Christian religious tradition (White 1967), and enlightenment thought (Cortner and Moote 1999). Closely related to the assumption of nature-culture dichotomy, another flawed assumption of conventional resource management is its conceptualization of ecosystem

dynamics as relatively stable and predictable, fluctuating around a single equilibrium (Folke 2006). Working together, these twin assumptions have impeded the accumulation of knowledge on the dynamic and reciprocal interactions between social and biophysical systems, thus leading to misinformed policies (Hughes et al. 2005; Folke 2007; Liu et al. 2007).

Over the last two decades, these older assumptions have begun to be replaced with alternative conceptualizations of social and ecological systems as coupled social-ecological systems, intricately interconnected and co-evolving across multiple spatial and temporal scales (Anderies et al. 2004; Folke 2007). The simultaneous study of the reciprocal interactions between social and ecological systems has revealed that coupled social-ecological systems exhibit the attributes of complex adaptive systems, such as nonlinearity, thresholds, emergence, surprise, scale, and path-dependency (Berkes 2004; Hughes et al. 2005; Folke 2006, 2007; Liu et al. 2007). Holling's (2001) panarchy theory models the dynamic cross-scale interactions among the various levels of social-ecological systems. Contrary to the assumption of ecosystems in a stable equilibrium, panarchy is a representation of the dynamics of social-ecological systems as a nested set of adaptive cycles in constant flux (Folke et al. 2010). Adaptive cycles represent the four phases of growth, conservation, collapse, and reorganization that each level of a social-ecological system constantly passes through (Carpenter et al. 2001). The sustainable management of such complex social-ecological systems calls for building resilience rather than the pursuit of efficiency and output maximization (Holling and Meffe 1996). These theoretical concepts that serve as the foundation for adaptive governance provide an opportunity for the reintegration of humans into the biosphere for ecosystem-based management of land and water resources (Chapin et al. 2009; Folke et al. 2011; Valman et al. 2015). For instance, in their recent analysis of adaptive governance regimes in the Kristianstads Vattenrike in Southern Sweden, the Great Barrier Reef in Australia, and fisheries in the Southern Ocean, Schultz et al. (2015, 7371) highlighted that "a mental shift, a reframing of the human-nature relation" was an essential component of the transition toward adaptive governance mechanisms that prioritized managing multiple ecosystem services and dealing with change across scales.

Integration of Diverse Sources and Types of Knowledge

The traditional separation between the social and ecological sciences has led to the marginalization of social issues in conventional resource management (Jacobson and McDuff 1998; Redman et al. 2004). The resource management process is often dominated by resource managers, scientists, and other professionals trained in the natural sciences (Endter-Wada et al. 1998). In these management processes, preference is given to positivist and reductionist scientific methods for generating quantitative data for the purpose of generalization and prediction of natural phenomena (Berkes 2003; Nelson et al. 2008). As a consequence, social science disciplines and non-scientific forms of knowledge have been virtually overlooked (Cortner and Moote 1999; Clark 2002). For instance, the field of water resources management has traditionally been dominated by hydraulic engineers (Raadgever et al. 2008), thus offering little space for social scientists. However, insights from the complex systems perspective highlight the fact that knowledge about such systems varies according to the scale of observation and is dispersed among different stakeholders. As such, no single analytical perspective or stakeholder group can yield adequate knowledge for making sense of the complexity of the whole system (Berkes 2004; Armitage et al. 2012). Each perspective offers a legitimate but incomplete account of the whole. Reductionist scientific methods are particularly ill-suited for understanding the non-linear relationships and emergent properties of complex systems (Costanza 1996; Nelson et al. 2008; Armitage et al. 2009).

As a response to the shortfalls of the dominance of reductionist and positivist science in conventional resource management, the adaptive governance approach calls for the integration of different knowledge systems (Nelson et al. 2008; West and Schultz 2015). In view of the inadequacy of single disciplinary approaches in the study of complex social-ecological systems, cross-disciplinary

approaches are gaining recognition in the study of land and water resource systems (Lélé and Norgaad 2005; Eigenbrode et al. 2007). For instance, the emerging field of socio-hydrology moves beyond the dominance of hydrology to integrate the social sciences in water resources research (Sivapalan et al. 2011). According to Sivapalan et al. (2014, 226), "Socio-hydrology is aimed at uncovering the dynamic cross-scale interactions and feedbacks between the natural and human processes that may give rise to water sustainability challenges that we face in the Anthropocene." Unlike multi-disciplinary and interdisciplinary approaches, the transdisciplinary field of socio-hydrology offers a deeper understanding of the dynamics of socio-hydrologic systems through its explicit emphasis on the reciprocal feedbacks between social and hydrologic systems (Sivapalan et al. 2011, 2014). Such cross-disciplinary approaches offer opportunities for utilizing knowledge from the social and biophysical sciences in the sustainable management of complex water resource systems.

Knowledge integration in adaptive governance occurs not only among academic disciplines across the social and biophysical sciences, but also includes the recognition of local and traditional ecological knowledge (Hughes et al. 2005; Cosens 2013; Morris and de Loe 2016). Berkes et al. (2000, 1252) define traditional ecological knowledge as "a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment." The authors contend that traditional ecological knowledge is typically associated with societies in which there is a historical continuity in resource use. Traditional ecological knowledge entails not only the observational knowledge derived from experience, but also includes the worldviews, beliefs, institutions, and practices within which such knowledge is nested (Berkes et al. 2000; Houde 2007). Traditional ecological knowledge differs from local ecological knowledge, which comprises a mix of scientific knowledge and practical knowledge (Olsson and Folke 2001).

Adaptive governance mechanisms also require the promotion of social learning (Folke et al. 2005; Bark et al. 2012). Reed et al. (2010) define social learning as "change in understanding that goes beyond the individual to become situated within wider social units or communities of practice through social interactions between actors within social networks." The social learning approach to knowledge differs from the reductionist approach that focuses on learning at the individual level. As Armitage et al. (2011) have noted, a focus on the individual ignores the social and institutional context that shapes learning processes. Social learning is collective learning that occurs through social interactions. Social interactions contribute to social learning through the direct transmission of information or through argumentation processes that lead to changes in ideas, worldviews, and rule systems (Reed et al. 2010). Social learning in adaptive governance processes is closely related to social memory – the reservoir of knowledge, practices, values, and worldviews that individuals and organizations have accumulated from past adaptations which is essential for dealing with future surprises (Adger et al. 2005). Such knowledge co-production requires decision-making processes that offer opportunities for meaningful participation and for bridging the epistemological differences among scientists, resource managers, resource users, and other stakeholders in the construction and interpretation of knowledge (Armitage et al. 2012). The vertical and horizontal linkages in the institutional structures and decision-making processes in the adaptive governance framework (discussed in subsequent sections) offer an enabling environment for knowledge co-production processes as well as the integration of science into policy (Bark et al. 2012; Aytur et al. 2015).

Promoting knowledge co-production and social learning in water resource management through adaptive governance may be enhanced using participatory action research methods, such as photovoice and photo-elicitation (Wang 1999; Bugos et al. 2014), participatory GIS (Brown et al. 2014), and participatory social network analysis (Fuller et al. 2012). These participatory approaches contribute to trust building, knowledge integration and sharing, capacity building, empowerment, and the flexibility to deal with change in water resource systems (Aytur et al. 2015; Madsen and O'Mullan 2016). For instance, Aytur et al. (2015) discuss the application of adaptive governance principles in

the development of an integrated climate change adaptation strategy for the town of Exeter, New Hampshire. Through the use of participatory action research methods, the project sought to promote regular interactions among diverse stakeholders at the local and state levels, and also to connect various epistemic communities including scientists and community groups. Results from an evaluation of the project showed that participants had become better informed about climate change issues (e.g., flooding and water quality degradation) and also had an enhanced ability to analyze climate change issues from multiple perspectives.

Adaptive and Integrated Management Goals

The emphasis of the command-and-control resource management paradigm on the maximization of economic benefits from selected components of biophysical systems that are assumed to be stable has been critiqued for eroding the resilience of social and ecological systems (Hughes et al. 2005; Holling 2012; Cosens 2013). Adaptive governance shifts the focus of resource management away from the pursuit of efficiency and optimization (Green et al. 2013), and instead offers an ecosystem-based framework for adaptive and integrated management of land and water resources (Engle et al. 2011; Bark et al. 2012; Valman et al. 2015; Akamani et al. 2016).

Adaptive governance embraces the holistic focus of ecosystem-based resource management on sustainability and resilience (Folke et al. 2005, 2011). Ecosystem-based management seeks to satisfy the range of social, economic, and ecological values desired by stakeholders while sustaining the capacity of the social-ecological system to produce those goods and services that sustain human well-being in the face of uncertainty (Hughes et al. 2005; Gunderson and Light 2006; Chapin et al. 2009). The pursuit of such holistic management goals provides an opportunity for integrating the diverse values and interests held by stakeholders, including the interests of traditionally marginalized groups in water resource governance, such as indigenous communities (Bark et al. 2012; von der Porten and de Loe 2014). While conventional integrated resource management has failed to address value conflicts through expert-driven rational-comprehensive planning approaches (Blomquist and Schlager 2005), the adaptive governance approach promotes the pursuit of integrated management goals by providing opportunities for negotiated solutions to conflicting values and knowledge uncertainties (Dietz et al. 2003; Nelson et al. 2008) while enhancing the coordination of responsibilities among diverse actors across scales and jurisdictions (Bark et al. 2012).

Besides the pursuit of an integrative agenda, another central component of adaptive governance is adaptive management (Gunderson and Light 2006; Walker 2012). Adaptive governance builds on the focus of adaptive management on dealing with uncertainties and surprises in social-ecological systems through learning (Karpouzoglou et al. 2016). However, adaptive governance broadens the scope of adaptive management by accounting for the wider social context within which ecosystem-based resource management occurs (Folke et al. 2005). As such, adaptive governance addresses the inadequate consideration of social and institutional issues that has impeded success in the implementation of adaptive management processes (Gunderson and Light 2006). In all, the adaptive governance approach provides enabling institutional structures and processes that facilitate integration within and across scales, as well as preparing coupled social-ecological systems to deal with uncertainties through adaptive management (Bark et al. 2012; Cosens 2013). Green et al. (2013) present an interesting case study on integrated and adaptive management in the Okavango River Basin of southern Africa. Through the coordinated efforts of actors across multiple levels from the local to the international, an integrated approach to addressing socio-economic and ecological concerns is being pursued through the Integrated River Basin Management Project. The authors contend that although the adaptive capacity of actors in the river basin has not recently been tested, there are indications of preparations for change and uncertainty through monitoring and information sharing, as well as opportunities for meaningful participation among actors.

Institutional Structures and Processes

The top-down institutional structures of the conventional water resource management paradigm have received widespread criticisms, including the

lack of fit between policy interventions and the scales at which problems occur (Lebel et al. 2008), lack of flexibility in adapting to change (Healey 1998), difficulty of integrating local knowledge (Nelson et al. 2008), and limited capacity for dealing with social-ecological complexity (Karkkainen 2005). Adaptive governance is a response to the shortfalls of both centralized and community-based institutional mechanisms. In their seminal paper on adaptive governance, Dietz et al. (2003) identify the institutional requirements of adaptive governance: availability of information, mechanisms for conflict management, inducement of rule compliance, provision of infrastructure, and preparedness for change. The authors propose three strategies for meeting these requirements: analytic deliberation, nesting, and institutional variety. These three strategies constitute the institutional structures and processes entailed in adaptive governance mechanisms that enable adaptive and integrated resource management.

Analytic Deliberation. Using public deliberation to inform scientific analysis is an effective way to integrate facts and values for good decision-making (Dietz 2013). The concept of analytic deliberation refers to a "Well-structured dialogue involving scientists, resource users, and interested publics, and informed by analysis of key information about environmental and human-environment systems" (Dietz et al. 2003, 1910). The wisdom in analytic deliberation is that it combines scientific analysis with public deliberation to inform better policies (Dietz and Stern 1998; Akamani and Wilson 2011). Whereas analysis entails the systematic application of rigorous and replicable procedures for data collection and interpretation, deliberation encompasses the formal and informal processes for communication and collective decision-making among scientists and other stakeholders (Tuler and Webler 1999; Webler and Tuler 1999). Analytic deliberation offers a more effective mechanism for dealing with the wicked problems that arise from the value conflicts and knowledge uncertainties in complex social-ecological systems than expert-driven rational-comprehensive planning processes (Ballint et al. 2011; Akamani et al. 2016). Analytic deliberation also offers opportunities for the integration of different types and sources of knowledge held by stakeholders (Corfee-Morlot et al. 2011), thereby enhancing prospects for the recognition of local and traditional ecological knowledge in adaptive governance processes. Such deliberation processes also meet the conditions for the emergence of social learning (Reed et al. 2010; Akamani and Wilson 2011), as well as the enhancement of trust and social capital among stakeholders (Dietz et al. 2003). In all, analytic deliberation addresses the need for inclusive and integrative institutional mechanisms for the transparent and evidence-based negotiation of trade-offs among stakeholders in the water governance process (Dietz and Stern 1998; Pahl-Wostl et al. 2013). Case studies from the broader literature on participation and social learning highlight that outcomes of such processes may be shaped by the patterns of interactions among participants (Crona and Parker 2012), the organizational structures guiding the process (Muro and Jeffrey 2012), and the duration of the process (Measham 2013). In the specific case of water resource management, Webler and Tuler (1999) offer a number of helpful guidelines for enhancing effective analytic deliberation processes. These include: ensuring a balanced representation of all stakeholders; motivating stakeholders to participate; creating opportunities for participation; addressing unequal access to the process, resources, information, and skills; use of facilitators; providing a safe environment for dialogue; and ensuring legitimacy of the entire process.

Nested Institutions. Dietz et al. (2003) also highlighted the need for nested institutions in the adaptive governance of social-ecological systems. As has been noted previously, a representation of social-ecological systems from the perspective of panarchy theory illustrates that social-ecological systems are composed of inter-dependent adaptive cycles that are nested across multiple levels and are constantly engaged in cross-scale and cross-level interactions (Holling 2001). Within such a multi-level system, top-down institutional arrangements that ignore these cross-scale issues often result in scale mismatches or the lack of fit between policy interventions and social-ecological problems (Cash et al. 2006; Folke et al. 2007; Olsson and Galaz 2009). The nested institutional structure of adaptive governance is an appropriate response to the scale issue in complex social-

ecological systems (Akamani and Wilson 2011). Nested institutions closely relate to the widely discussed concept of polycentric institutions (Marshall 2009). Ostrom (2010, 552) defines polycentric institutions as those "characterized by multiple governing authorities at differing scales rather than a monocentric unit." Each level within the polycentric system retains some autonomy to make and enforce rules (Marshall and Smith 2010), and responsibilities among levels of the institutional structure are allocated according to the principle of subsidiarity whereby responsibilities are devolved to the lowest appropriate level (Marshall 2009). In addition to addressing problems associated with scale mismatch, the polycentric institutional structure of adaptive governance offers several advantages, including the promotion of learning and experimentation at lower levels (Ostrom 1999), creating space for engagement of local communities in multi-level processes (Akamani and Wilson 2011; Bark et al. 2012), and providing redundancies that enhance system performance in the face of uncertainty (Dietz et al. 2003; Olsson and Galaz 2009). The vertical and horizontal linkages in such nested polycentric institutions could also contribute to integrated resource management goals by reducing or eliminating conflicts and competition among alternative uses (Marshall and Smith 2010; Pahl-Wostl et al. 2013). The governance mechanism in the Okavango River Basin provides a good illustration of nested institutions. Community-based conservation efforts at the local level, protection by constitutions and government ministries at the national level, a river basin commission at the watershed level, and international transboundary agreements on the management of the shared water resource provide multiple, overlapping levels of governance (Green et al. 2013).

Institutional Variety. The strategy of institutional variety addresses the need for diversity in the institutional mechanisms for adaptive governance processes (Dietz et al. 2003). Following Hardin's (1968) publication of "The tragedy of the commons," states and markets have usually been posited as panaceas in conventional resource management. However, a key insight from the common pool resource literature is that no single type of institution, whether states, markets, or communities, can be expected to function effectively, efficiently, and sustainably all the time (Ostrom et al. 1999). Since success and failures are associated with each of these types of institutions, the use of a diversity of institutions is an effective strategy for reducing the vulnerability of social-ecological systems (Berkes 2007). The issue of diversity is of central importance to resilience and adaptive governance. From an ecological perspective, functional and response diversity is an essential requirement for resilience (Hughes et al. 2005). Similarly, from the social perspective, institutional diversity enhances the integration of diverse perspectives from the different institutional approaches, thereby promoting the use of new ideas and techniques, as opposed to reliance on a single approach (Pahl-Wostl et al. 2013). This diversity enhances the overall resilience and effectiveness of the system. As Dietz et al. (2003, 1910) have noted, "Innovative rule evaders can have more trouble with a multiplicity of rules than with a single type of rule." For example, the governance of the Okavango River Basin involves community-based organizations, government representatives of the riparian states, and international non-governmental organizations in promoting adaptive and integrated management (Green et al. 2013). Similarly, the Blackfoot Challenge in Montana, a collaborative mechanism which emerged to address various social and ecological challenges in the 1.5 million acre Blackfoot watershed in the 1990s, comprised diverse actors, including private landowners, state representatives, federal agencies, and conservation organizations, such as the Nature Conservancy (Weber 2012; Wyborn and Bixler 2013).

Challenges in Adaptive Water Governance

The previous section of this paper highlighted the key features of adaptive water governance and their potentials for integrating the human dimensions into the governance of water resources in the face of uncertainty. However, a number of critical challenges will need to be overcome in order to realize the potentials of adaptive water governance (Akamani 2014).

At the philosophical level, differences among scientists, resource managers, and other stakeholders on fundamental issues, such as the value of nature

and the place of man in nature constitute potential stumbling blocks to adaptive water governance. For instance, lessons from ecosystem management suggest that differences in philosophical perspectives, ranging from anthropocentric to biocentric or ecocentric perspectives account for conflicts in the management process (Endter-Wada et al. 1998; Yaffee 1999; Behnken et al. 2016). Similarly, the limited implementation of active adaptive management and adaptive governance has been attributed to the lack of political will by decision-makers to embrace uncertainty (Walters 2007; Valman et al. 2015). In this regard, Dietz (2013) highlights the cognitive limitations in human ability to understand uncertainties and non-linear relationships in complex adaptive systems.

With regard to knowledge, the integration of scientific and non-scientific knowledge, as well as the promotion of social learning in adaptive governance, promise to offer a holistic understanding of complex social-ecological systems. However, epistemological differences in the foundations of western science and traditional knowledge, as well as differences in worldviews among stakeholders in social learning processes can constrain learning and knowledge integration (Berkes 2009; Reed et al. 2010). Also, institutional challenges, such as power imbalances among stakeholders, often lead to the marginalization of local and traditional knowledge (Houde 2007; Armitage et al. 2011). Finally, attitudinal issues, such as the lack of trust and mutual respect for local and traditional knowledge, need to be overcome (Berkes 2009; Armitage et al. 2012).

The institutional structures and processes of adaptive governance provide a promising mechanism for integrating diverse stakeholder values across scales, as well as learning and adapting to change and uncertainties. However, transitions toward such adaptive governance institutions can be constrained by the path-dependent effects of the dominant top-down institutional mechanisms associated with the command-and-control paradigm (Pahl-Wostl et al. 2007, 2009; Valman et al. 2015). The complexity associated with the diversity of interests and values across the multiple scales of adaptive governance also presents challenges for collective decision-making (Ostrom et al. 1999; Huitema et al. 2009; Dietz 2013). Importantly, Koontz et al. (2015) have cautioned that adaptive governance institutions could potentially yield undesirable social and ecological outcomes, such as widening inequalities and resource degradation. Contextual factors, such as the influence of vested interests, as well as pre-existing inequalities in access to power, information, resources, and opportunities could shape the outcomes of adaptive water governance. For instance, Mostert (2012) analyzed polycentric water governance on the small Dutch Island of IJsselmonde over a thousand-year period and found that contrary to the expected flexibility and adaptability of such systems, change was often slow due to the role of vested interests, the lack of willing and capable leaders at higher levels, and emotional attachments to old institutions, among other constraints.

Conclusion

The shortfalls associated with the command-and-control paradigm of water resource management have created awareness about the need to integrate the human dimensions and to prepare for uncertainties in the governance of water resources. In this regard, this paper has argued that adaptive water governance addresses these challenges as it provides opportunities for integrating the human dimensions into the assumptions, management goals, knowledge systems, and institutional mechanisms for water resource governance, while also allowing flexibility in the face of uncertainty. Expected benefits of such integration include enhancing good governance and sustainability and resilience in water resource systems. In spite of these benefits, it is worthwhile to note that adaptive governance is not a panacea (Koontz et al. 2015). The meaning of adaptive water governance remains ambiguous, its implementation may be constrained by several factors, and outcomes may not always be equitable or sustainable. Greater theoretical and methodological contributions from researchers across various social science disciplines, as well as enhanced awareness, willingness, and capacity of decision-makers, resource managers, and the general public is needed to enrich our understanding of adaptive water governance and to enhance its successful implementation.

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