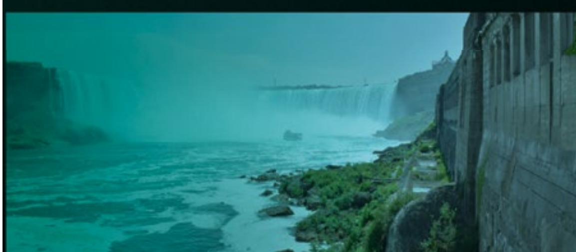
Julia Baird
Ryan Plummer
Editors

Water Resilience

Management and Governance in Times of Change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Preface and Acknowledgements

Water is necessary for life and its management is, and continues to be, intertwined with human history. In the twenty-first century an unprecedented drama is unfolding. Crises of water abound: billions of people lack access to safe drinking water or sanitation; freshwater and other ecosystems are extensively transformed and degraded; concerns about water scarcity and insecurity are growing; water infrastructure is deteriorating; water related disasters are anticipated to increase; and development continues in an unsustainable manner. The prominent presence of water on *The 2030 Agenda for Sustainable Development*, adopted in 2015 by all Member States of the United Nations, is thus unsurprising. Goal Six ('the water goal') explicitly seeks to ensure availability and sustainable management of water and sanitation for all. It is evident that water actually underpins many of the sustainable development goals. The sustainability of our water is essential for both people and the planet.

The contemporary and future situation is not only unparalleled due to the severity of the water crises, but also because it is unfolding in the Anthropocene – an era in which the influences of humans are a major force of global environmental change. Climate change, along with other drivers, will exacerbate other stressors and is leading to a grim outlook on water futures. Accompanying advances in understanding of systems require re-visiting and re-evaluating past foundational assumptions about the stationarity of water systems. The fluctuation of natural systems within a predictable envelope of variability is unlikely. Complex interactions between social and ecological systems are expected as is interplay within and across levels and scales. At the same time, dialogue is occurring about water rights, responsibilities and values.

Against this backdrop, a confluence of professional experiences and scholarly developments gave impetus to this volume. Limitations of the command and control (government-led) approach to managing resources served as a departure point for much of our research. Consequently, we concentrated on alternative approaches to how people manage and govern aspects of water resources, especially at local scales. Our experiences made clear the variety of these approaches emerging in practice as well as the rich opportunities for them to concomitantly address water-related issues while enhancing community vitality. It also became increasingly evident in our work that, despite the specific water issue, opportunity and/or scale, individuals and organizations were confronting matters of complexity, uncertainty and contested values. Social-ecological resilience resonated with us largely due to our observations from these early experiences and we started incorporating salient constructs from that scholarship into our water-related research. Of course, many others also saw the synergies between water and resilience, and it was only a matter of time until a 'new water paradigm' emerged in response to the contemporary situation and future challenges. While scholarship on water resilience is growing, it appears to be outpaced by enthusiasm 'on the ground' and in policy discussions about changing how we approach water. Consequently, we saw the need for a volume which deepens knowledge relating to management and governance dimensions of water resilience as well as more fully understand the implications for practice and policy.

We were extremely pleased with the generous response from our colleagues when we communicated the need for this volume and invited them to contribute to it. We sincerely appreciate the thoughtfulness, dedication and time each of the contributors gave to their chapters. What emerged from these contributions was two distinct but related approaches to the governance and management dimensions of water resilience. The first was an application of the water resilience concept to examine water systems. The five chapters contained therein come from a wide range of contexts, from the EU's Water Framework and Flood Directives to polycentric governance potential in South America to agricultural pollution reduction. The second approach that emerged was a focus on further development of the water resilience concept. The six chapters that complete this part cover a diverse range of topics including transformations, cross-scale governance and social learning, among others. We believe that the volume as a whole provides an overview of the current state of water resilience literature; delves into the question of how water resilience is applied in real world systems; and continues to move the conversation about water governance and management through a resilience lens forward. This is exactly what we hoped to accomplish with the volume and we thank our contributors for their support of this vision.

Ensuring the integrity of this volume was paramount to us as co-editors. Each of the chapters was subject to single-blind review by two subject matter experts. The feedback offered by the reviewers was critical and thought-provoking. Authors carefully considered and responded to their comments, which ultimately strengthen the overall quality of the work. We express our appreciation to the reviewers who wished to remain anonymous and to the following individuals: Jason Alexandra, Lena Blom, Matthew Colloff, Robin Craig, Jampel Dell'Angelo, Sherman Farhad, Catherine Febria, Jean Fried, Oliver Fritch, Stefan Gelcich, Margot Hurlbert, Marney Isaac, Åse Johannessen, Rolf Larsson, Leslie Morris-Iveson, Gül Özerol, Ryan Plummer, Panchali Saikia, Chandni Singh, Micaela Trimble and Barbara Veale. We also wish to thank Sherman Farhad and Ryan Plummer for offering insightful comments on the opening and closing chapters of the book, respectively.

Finally, this book would not have been possible without several sources of support. We are grateful for the assistance of Gillian Dale, Sherman Farhad, Amy Lemay, Amanda Smits and Stephanie Tulipano in the preparation and formatting of this book. From the Springer team, we wish to express our appreciation to Margaret Deignan for her immediate interest in this volume when we approached her in 2017 and her continued enthusiasm throughout the project. We also thank Malini Arumugam for her day-to-day support on all aspects of the book. Finally, Julia's involvement in this book was supported in part by the Canada Research Chairs program.

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March 2020

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Part I
Introduction

The Emergence of Water Resilience: An Introduction

Ryan Plummer and Julia Baird

Abstract Water quality and availability is critical for sustaining life on earth. However, lack of access to potable water and safe sanitation services for billions of people, deteriorating infrastructure, degradation of ecosystems, and impacts of climate change signal a global water crisis. This crisis is unfolding in the era of the Anthropocene, where human actions are a major driving force of change at a global scale. Instability and surprise are expected in this era, where the interactions and impacts of our decisions can have far-reaching and uncertain impacts. How do we navigate water management and governance in the face of these challenges? A new water paradigm – water resilience – has emerged that acknowledges and considers the complex, dynamic and uncertain nature of social-ecological systems. It emphasizes the need for systems to both persist and provide a set of functions and to adapt to changing conditions. Water resilience has been advanced in scholarship over the past 15 years and is gaining traction in practice and policy realms worldwide. Acknowledgement of the complex nature of water systems coincides with the recognition that the past, command-and-control approaches to management and governance, must give way to inclusive, adaptive and polycentric approaches. Considerable inroads are being made into how we advance management and governance approaches in this new water paradigm. The contributors to this volume represent voices that are making important contributions to the way forward.

1 Water in the Anthropocene

Water is essential to people and the planet. It is central to life processes and "although often perceived to be pretty ordinary, water is the most remarkable substance" (Chaplin, 2001, p. 54). Water enables biochemical functions, provides habitat,

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stabilizes temperature, supports economic sectors, and inspires artists, among other functions. Ultimately, water determines the sustainability of living systems and as such is "…the bloodstream of the biosphere" (Ripl, 2003, p. 1921).

The twenty-first century is being hailed as the century of the 'global water crisis' (Bunn, 2016, p. 1). Although water appears abundant on Earth, covering 70% of the surface, only two and a half percent of all water is freshwater (Guppy & Anderson, 2017), and less than one percent is available for human and ecosystem support (Randhir, 2012). Among the litany of evidence pointing to a water crisis: 2.1 billion people do not have access to safe drinking water (World Health Organization [WHO], & United Nations Children's Fund [UNICEF], 2017); surface freshwater systems are some of the most transformed systems on the planet (Carpenter, Stanley, & Vander Zanden, 2011); 4.5 billion people do not have safe sanitation services (WHO & UNICEF, 2017); cooperative agreements are absent in 60% of trans-boundary basins (Wolf, 2002); and, water insecurity is estimated to cost the global economy $500 billion dollars annually (WWAP, 2016). As opposed to a singular water crisis ahead, a plurality of water crises loom: water scarcity and insecurity; disasters related to water; drinking water, sanitation and health; destruction and deterioration of water infrastructure; unsustainable development; and, degradation of ecosystems (Guppy & Anderson, 2017).

Whereas concerns about water have been focused on the biophysical environment, this drama is unfolding in the Anthropocene (Bunn, 2016; Rockström et al., 2014; Vörösmarty, Pahl-Wostl, Bunn, & Lawford, 2013) where human influences on ecosystems are recognized as a major driving force of global environmental changes (Crutzen, 2002; Steffen et al., 2007). Rockström et al. (2014) connect the new level of global concern about water (Vörösmarty et al., 2013) to exponential increases in environmental impacts since the 1950s globally associated with the great acceleration, where population growth, economic activity and energy consumption have been increasing extremely rapidly (Steffen et al., 2005). Global trends in these stressors and others (arable land, deforestation, carbon dioxide concentrations) correspond with trends in water quantity (increasing water use) and decreasing quality (nitrogen fluctuations in coastal zones) over time (Zimmerman, Mihelcic, & Smith, 2008). Human processes and activities (demographic, economic and social drivers) impact water and are also shaped by a range of factors (innovations in technology, financial and institutional conditions, climate change) (United Nations World Water Assessment Programme [WWAP], 2009). While the list of human drivers exerting pressure on water is extensive, both natural and human drivers are inter-related and should not be considered in isolation (WWAP, 2009; Zimmerman et al., 2008).

A critical concern for water in the Anthropocene is climate change. Climatic drivers have and continue to be a major stressor on water (Bates, Kundzewicz, Wu, & Palutikof, 2008) and their interactions with other drivers will exacerbate other pressures. This has been highlighted by Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) (Jimenez Cisneros et al., 2014). Among the key risks at a global scale identified by the working group: increasing concentrations of greenhouse gas significantly increase freshwater-related risks of climate change; renewable surface water and groundwater is projected to be reduced significantly in dry subtropical regions, intensifying competition among users; variations in flood frequency is implied from projections; and, the frequency of droughts in present dry regions is likely to increase (Jimenez Cisneros et al., 2014). Climatic drivers, in concert with other pressures on water result in increasing scarcity, decreasing quality and serious concerns about the future of freshwater systems and the ecosystem services they provide (Jimenez Cisneros et al., 2014; Rockström et al., 2014). Projections about the future state of water are grim. The most recent annual study by United Nations World Water Assessment Programme (WWAP)/UN-Water (2018) observes: the deterioration of water quality is widespread and expected to continue; the greatest natural disaster risks of drought and soil degradation are likely to worsen; and, by 2050 water shortages may affect 4.8–5.7 billion people while 1.6 billion people will be at risk of floods.

Instability and surprise are new essential considerations of the emerging water agenda in the Anthropocene (Rockström et al., 2014). Rockström et al.'s (2009) planetary boundary framework seeks to define the dynamic boundaries for critical Earth System processes past which major tipping points may be crossed or fundamental preconditions for development (social and economic) altered in the context of the Anthropocene. Global freshwater use is one of nine planetary boundaries considered and initial analysis revealed it is presently in a safe operating space, but when considering future demands, freshwater may be fully committed already (Rockström et al., 2009). An updated assessment of global freshwater use confirmed it was within the planetary boundary (Steffen et al., 2015). However, the line of argument for the planetary boundary on freshwater has been critiqued as speculative and lacking evidence for the hypothesis or risks associated with crossing the boundary (Heistermann, 2017). Most recently, Jaramillo and Destouni (2015) argue that recent advances not considered imply the consumptive use of freshwater has passed this planetary boundary.

In sum, "the world continues to face multiple and complex water challenges that are expected to intensify in the future" (WWAP/UN-Water, 2018, p. 10). Water is foundational to achieving the 2030 Agenda for Sustainable Development, but unfortunately early indications on progress towards clean water and sanitation (Sustainable Development Goal 6) suggest 'the world is not on track' (WWAP/UN-Water, 2018). Navigating water challenges in the Anthropocene is essential for sustainability and urgently needed.

2 Water Resilience

A new water paradigm is emerging. This new paradigm is not an isolated response to contemporary and future challenges. As Pahl-Wostl, Jeffrey, Isendahl, and Brugnach (2011) observe, "many voices in science and policy have advocated a paradigm shift in water management—both from a normative (it should happen) and a descriptive (it happens, and how) perspective" (p. 837). It draws upon advances in understanding how the world works as well as broadening conversations about what and whose values matter. Freshwater systems have complex interactions between social and ecological systems that are constantly being influenced by many forces, both internal and external, at a range of levels (Pahl-Wostl et al., 2011; Schoeman, Allan, & Finlayson, 2014). They are thus aptly conceived as social-ecological systems – a view stressing the linked nature of social and ecological systems and the integrated idea of humans-in-nature (Berkes & Folke, 1998).

In this new paradigm, social-ecological systems must persist, providing a set of functions, but also change – this tension between persistence and change is understood as 'resilience' (Folke, 2003; Rockström, Falkenmark, Lannerstad, & Karlberg, 2012; Walker, Holling, Carpenter, & Kinzig, 2004). 'Climate change has changed the water rules' (Appleton, Kabat & van Schaik, 2003) and past assumptions about the stability of systems upon which conventional water management was predicated are no longer valid (Milly et al., 2008). Whereas natural systems once tended to fluctuate within a predictable range of variability (i.e., stationarity), a new 'predictable envelope of variability' is unlikely in the future (Bates et al., 2008; Bergkamp, Orlando, & Burton, 2003; Milly et al., 2008).

Water resilience as a new water paradigm has gained traction in policy discussions, in practice and in scholarship. Water resilience has become a popular rallying cry for the urgent need for a different approach to water. Writing in the context of the World Economic Forum, Fred Boltz (Managing Director, Ecosystems, the Rockefeller Foundation) responds to the question "How do we prevent today's water crisis becoming tomorrow's catastrophe?" by making a case for freshwater resilience – "it's clear we need to change. It is time to embrace a new paradigm for solving our growing crisis: valuing water wisely, and managing it using principles of sustainability, inclusion and resilience" (Boltz, 2017, p. 1). Workman (2017), covering the same event explains "why understanding resilience is key to water management" in a piece for the International Water Association and highlights Johan Rockström's assertion that "…we need a mind shift by water professionals if we are to avoid a global disaster" (p. 1).

Water resilience is capturing the imagination of individuals, organizations, and agencies worldwide and starting to gain traction 'on the ground.' Confronted with severe drought and insufficient confidence in past approaches, Cape Town announced a new approach to water focused on resilience and developed a water resilience plan for the city. Although the predicted date the taps run dry or 'day zero' has been put off, "Cape Town's predicament provides a global warning about the difficulty of ensuring water resilience in a warming world, even if, as with Cape Town, climate change is firmly on the agenda of city managers" (Welz, 2018, p. 5). Patrick Decker, CEO of the international water business Xylem, on CNBC (2018) spoke to tackling global water challenges and asserted that "water resilience is a global issue" (online). The United States Environmental Protection Agency (2018, online) has framed their approach to water and wastewater utilities in terms of resilience and offers a 'Route to Resilience' tool to guide utility personnel. In January 2018 five cities (Amman, Cape Town, Mexico City, Greater Miami and the Beaches, and Hull) were selected to develop a global water resilience framework. The framework, overseen by representatives of prominent organizations (The Rockefeller Foundation, 100 Resilient Cities, the World Bank, University of Massachusetts-Amherst, the Alliance for

Global Water Adaptation (AGWA) and The Resilience Shift) will "…be a global standard for water resilience, which enables cities to diagnose challenges related to water and utilize that information to inform planning and investment decisions" (Adlington, 2018, p. 3).

Freshwater for Resilience: A Shift in Thinking, provides a scholarly entrée into the topic of water resilience. Therein, the fundamental shift in thinking that underpins it is set out by Folke (2003, p. 2028):

> It requires a shift in thinking from focusing on controlling change in an engineering fashion for optimal solutions to accept that change is the rule rather than the exception (Holling & Meffe 1996; van der Leeuw 2000). The old way of thinking implicitly assumes a stable and infinitely resilient environment. The new perspective recognizes that resilience can and has been eroded and that the challenge facing humanity is to try to sustain desirable pathways for development in the face of change (Carpenter et al. 2001; Folke et al. 2002). The concept of resilience shifts perspective from the aspiration to control change in systems assumed to be stable, to sustain and enhance the capacity of social–ecological systems to cope with, adapt to, and shape change and learn to live with uncertainty and surprise (Gunderson & Holling 2002; Berkes et al. 2003)

Scholarship on water resilience has since grown and shows strong associations with the core of the new water paradigm (e.g., Schoeman et al., 2014). While several voices advocate a paradigm shift in water management, a dominant theme is "the need to develop understandings of water resources and their management as a complex system" (Pahl-Wostl et al., 2011, p. 843). The substantial body of work by Johan Rockström and colleagues at the Stockholm Resilience Centre (e.g., Falkenmark, 2017; Falkenmark & Rockström, 2010; Rockström, 2003; Rockström et al., 2014, 2014) have considerably shaped how the area of study has developed. The 2014 book by Rockström et al. provided insights into 'water resilience for human prosperity' with a focus on green and blue water resources, land and water integration, social-ecological systems and resilience, reconnecting to the biosphere, and cross-scale interactions in the context of global change.

Key constructs in global change scholarship such as vulnerability and adaptive capacity (Miller et al., 2010; Smit & Wandel, 2006) are also addressed. Attention has been focused on specific disturbances including flooding (e.g., Baird et al., 2016; Liao, 2012; Morrison, Noble, & Westbrook, 2018) and drought (e.g., Falkenmark & Rockström, 2008; Rockström, 2003). Studies of water resilience in urban settings often connect with the challenges of flooding (e.g., Head, 2014; Jiang, Zevenbergan, & Fu, 2017), and some specifically address how the concept of resilience relates to water services and infrastructure (e.g., Johannessen & Wamsler, 2017; Kennedy, Baker, Dhakal, & Ramaswami, 2012). It is clear that the boundaries around these areas of focus are fuzzy; there are important relationships between and among them.

An initial observation from the literature is that definitions of water resilience are rare. When the term water resilience is defined, it appears to capture slightly different concepts or have varied points of emphasis, but a common focus on social-ecological systems. For example, Rockström, Karlberg, and Falkenmark (2011) write that "building in water resilience – i.e. strengthening a water system's capacity to cope with global environmental change while retaining essentially its same structure and function – will be equally important" (p. 133). A few years later, Rockström et al. (2014) elaborate:

> our focus is on the role of water in the resilience of social-ecological systems in an era of rapid global change. Our shorthand for this is the term 'water resilience' which should not be interpreted as the resilience of water, as our focus is the reverse, i.e., the role water plays in the resilience of ecosystems and societies. (p. 32)

Rodina (2019), recognizing water resilience is variously and poorly understood in terms of meaning, applications and implications, carried out a systematic mapping review of the associated peer-review literature form 1982–2017. Results capture the state of the literature (e.g., countries from which scholarship is published, journals in which it appears) and provide the following key insights.

- Resilience definitions varied considerably. The largest proportion drew upon the engineering conception of resilience, with a noticeable growth in the use of other definitions more recently.
- Water supply, water resources management and drainage/stormwater management were the domains to which resilience was most prominently applied. While water distribution systems emerged as the scale at which resilience was most applied, the multiplicity of applicable scales as well as lack of scale specificity and interactions were recognized overall.
- A majority of the literature concentrated on the resilience of built infrastructure systems, over two-thirds was unspecific as to the resilience of whom, and the most common drivers cited were climate change, drought and social-economic and political stressors.

Drawing on these conceptualizations and recognizing the key role that water plays in earth's systems, as well as the extent to which it has been degraded (Rockström et al., 2014, 2014), we define water resilience in similar terms as social-ecological resilience: "the capacity to adapt or transform in the face of change in social-ecological systems, particularly unexpected change, in ways that continue to support human wellbeing" (Folke, Biggs, Norström, Reyers, & Rockström, 2016, online) but with a focus on water systems in particular (Eriksson, Gordon, & Kuylenstierna, 2014; Rockström et al., 2011).

3 Resilience: An Emerging Perspective on Water Management and Governance

This book is about solving water challenges and realizing opportunities for sustainability in the Anthropocene. Altering our thinking about water is foundational to water resilience and has profound implications. Hence, the focus of this book is on the management and governance dimensions of water resilience.

It is important at the outset to recognize the success of ‘conventional’ approaches in some circumstances as well as their critiques. Tremendous success was achieved during the twentieth century in addressing some water challenges. Massive infrastructure construction dominated the twentieth century water agenda and this “hard path” resulted in greater hydropower generation, irrigation for agriculture, reduced the risk of droughts and flooding, and reduced the risk of water-related diseases, ultimately benefiting billions of people (Gleick, 2003). Marked progress in the twentieth century also came from the first generation of environmental policy and an emphasis on regulations:

> The regulations unquestionably produced dramatic environmental improvements. Many dirty waters became swimmable, fishable, and drinkable again. Boston Harbor, Galveston Bay, and the Connecticut River are all far cleaner. Even, Cleveland’s Cuyahoga River, famous for its oily filmy and obnoxious smell – and for catching fire in 1969 – now sports tourist cruise ships and only occasional residue. (Kettl, 2002, p. 1)

And yet, as the opening section of this volume conveys, the contemporary as well as future status of freshwater is precarious. As Gleick (2003) observes, the ‘hard path’ approach which brought tremendous benefits also produced serious economic, social and ecological costs that were often unanticipated. These unexpected negative consequences underscore the pathology of natural resource management (sensu Holling & Meffe, 1996) as top-down (i.e., state-centred) command-and-control. Concerns about command and control approaches have been expressed for the substantial costs of enforcement and compliance, the polarization and conflicts accompanying regulations, and the lack of effectiveness in addressing challenges with properties of complexity and uncertainty (Durant, Chun, Kim, & Lee, 2004; Holling & Meffe, 1996; Kettl, 2002). More of the same command and control approach will not sustain water for ecosystems or humans in the future (Garmestani, Allen, & Cabezas, 2008; Gleick, 2003; Holling & Meffe, 1996; Milly et al., 2008; Pahl-Wostl et al., 2011).

It is also important to acknowledge that the shift to water resilience coincides with the broadening conversation about who and how decisions are made about water. Most poignantly, the Global Water Partnership (2000) asserted that “the water crisis is mainly a crisis of governance” (p. 16); an assertion echoed by the United Nations World Water Assessment Programme (WWAP, 2003) and most recently by the Organization for Economic Co-operation and Development (Organization for Economic Co-operation and Development, [OECD], 2018). Governance is “a social function centered on steering human groups towards mutually beneficial outcomes and away from mutually harmful outcomes” (Brondizio, Ostrom, & Young, 2009, p. 255). Governance emerged as a critical concern in the context of water in the first decade of the twenty-first century (Rogers & Hall, 2003; Scholz & Stiftel, 2005). de Loë, Armitage, Plummer, Davidson, and Moraru (2009) draw upon developments in environmental governance during this period and characterize water as undergoing a transition from government to governance. While not exclusive to water, Lemos and Agrawal (2006) highlight the general rise of alternative or hybrid forms of governance. These governance arrangements are required to address integration, coordination, and multiscale considerations (Lockwood, Davidson, Curtis, Stratford, & Griffith, 2010) and create a 'fuzzy boundary' between natural resources management and governance (Plummer, Armitage, & de Loë, 2013). The study of water governance continues to intensify (e.g., Bakker & Cook, 2011; Biswas & Tortajada, 2010; Gupta, Pahl-Wostl, & Zondervan, 2013; Ingram, 2011; Pahl-Wostl, 2015; Woodhouse & Muller, 2017). Commitments to mainstreaming associated principles appear to also be gaining uptake. For example, 65 signatories from across sectors committed to implement the OECD (2015) principles of water governance.

While governance has taken centre stage in the context of water and coincided with increasing interest in resilience, it is only recently that an attempt was made to gain consensus about the key attributes for governing aquatic ecosystems to ensure resilience. Plummer et al. (2014) conducted a two round Delphi of global experts on water governance and resilience with the objectives of gaining consensus on "1) governance attributes that indicate specified resilience; 2) governance attributes that denote general resilience; and, 3) practices or activities that enhance governance ability to respond to shocks and disturbances" to consolidate the state of thinking about governance of aquatic systems and resilience (p. 3). Attributes and activities for which agreement was established are summarized below, with references to specified resilience (SR), general resilience (GR) and practices and activities.

Specified and general resilience attributes of aquatic system governance

- Participant diversity and equity (SR) and inclusive participation (GR)
- Effective (SR) and strong (GR) leadership
- Polycentric governance with boundary organizations (SR), decentralized governance (GR)
- Social memory (SR)
- Capacity for self-organization (SR)
- Adaptability, flexibility of planning processes (SR) and institutional flexibility (GR)
- Precautionary risk assessment and reduction strategies (SR)
- Planning strategies that include a wide range of ecosystem services (GR)

Practices and activities that enhance governance resilience

- Forums for participation
- Improved transparency of decision-making
- Planning processes that are participatory and deliberative

Rodina's (2019) systematic mapping review complements the Delphi study by Plummer et al. (2014) and provides a synopsis of the features or characteristics of resilient water systems from the literature. She initially identified the system characteristics by categories (systems in general, social systems, built/natural systems) and then explores in greater details the institutional, governance and practical dimensions. Water resilience literature has clearly focused on technical solutions, with over half of the papers containing no mention of institutional or governance processes. In focusing on these aspects, she revealed the 17 governance institutional processes through which resilience is achieved – the four most common attributes being unspecified (57% of all papers), collaborative processes (24% of all papers), stakeholder engagement (20% of all papers) and government-led top down (16% of all papers). Interestingly, building resilience is framed by a majority of the papers as the responsibility of water managers and conventional actors in water governance. Further examination of these papers leads Rodina (2019) to observe that "…stakeholder engagement and participation tend to be seen as processes that help get buy-in or social acceptance of resilience building actions that remain predominantly decided on by governments and water managers. This implies that participation tends to be seen as important only in later stages of resilience-building, not necessarily in the planning and strategic decision-making ones" (p. 6).

While the Delphi study by Plummer et al. (2014) and review by Rodina (2019) sought to bring together a consolidated position on the subject, they also provided a glimpse into just how intertwined the area of scholarship is with other concepts and future directions in water management – a trend that is clearly continuing (see Akamani, 2016; Cosens & Gunderson, 2018; Schoeman et al., 2014). Plummer et al. (2014) identified approaches to management, governance and resilience that illustrate some of the points of coalescence and/or cross-fertilization among resilience and water scholars in this regard.

Adaptive management is one of the first approaches advocated as a way to bring ideas of governance and resilience together (Plummer et al., 2014). As initially conceived (e.g., Lee, 1993; Walters, 1997; Walters & Holling, 1990), adaptive management is oriented to 'learning by doing' through iterations of assessing opportunities, designing policies as experiments, implementing actions, and adjusting course in light of monitoring and evaluation. Adaptive management has thus given impetus to social learning as an imperative in water resources (e.g., Ison, Roling, & Watson, 2007; Pahl-Wostl, Mostert, & Tàbara, 2008). Catalyzing adaptive water management requires major transformation processes as current approaches are rigid and inflexible – built on the legacy of command and control (Pahl-Wostl, 2007) and are slow to change due to inertia and path dependence of prevailing regimes (Pahl-Wostl, 2007; Pahl-Wostl, 2008).

A second, longstanding and foundational approach (introduced in 1977 at the United Nations Conference on Water) is *integrated water resources management* (IWRM) (Grigg, 2008; Rahaman & Varis, 2005). The Global Water Partnership (Agarwal et al., 2000) defines IWRM as "…a process which promotes the co-ordinated 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" (p. 22). IWRM has been criticized (e.g., Biswas, 2004, 2008; Hering & Ingold, 2012; Jeffrey & Gearey, 2006), for example, for the approach's inability to address the increasing lag between reforms put forth by policy makers and understanding freshwater resources and their governance (Galaz, 2007). Galaz's reassessment of IWRM in this light encourages rethinking key components to better enable addressing challenges of complexity and change. Others have continued to build on and extend the initial conceptualization of IWRM. For example, Rockström et al. (2014) argue that "… the evidence of rising water-related shocks and interactions in the Anthropocene requires the emergence of a deeper social-ecological resilience-based approach to integrated land and water-resource management" (p. 1250).

Finally, use of the term *adaptive governance* has grown significantly since being introduced by Dietz, Ostrom, and Stern (2003) and Folke, Hahn, Olsson, and Norberg (2005), although neither consistent use of the term nor an explicit research agenda have coalesced (see Chaffin, Gosnell, & Cosens, 2014 for a summary). Adaptive governance "is an outgrowth of the theoretical search for modes of managing uncertainty and complexity" and championed in response to the need for:

> …new approaches to environmental governance capable of confronting landscape-scale problems in a manner both flexible enough to address highly contextualized SESs and dynamic and responsive enough to adjust to complex, unpredictable feedbacks between social and ecological system components. (Chaffin et al., 2014, online)

Plummer et al. (2014) elaborate upon this challenge and identify varied terms (e.g., adaptive co-management, collaborative management, resilience management) used to capture particular aspects of governance and resilience. Folke (2003) anchored this suite of approaches by sketching out the social dimension of freshwater management, social features for resilience, and multi-level governance of catchments. Considerable inroads are being made from conceptualizing alternative approaches to water management and gaining experience from novel governance strategies suited to addressing problems characterized by complexity, uncertainty, and contested values (e.g., Cosens et al., 2017; de Loë & Patterson, 2017; Fish, Ioris, & Watson, 2010; Huitema et al., 2009; Innes & Booher, 2010; Moss & Newig, 2010; Plummer et al., 2014, 2017; Rodina, 2019).

Opportunities abound to deepen knowledge relating to management and governance dimensions of water resilience, extend scholarship into new areas, and better understand the implications for practice and policy. Navigating change is paramount in the Anthropocene and cultivating capacities for adaptation and transformation is essential.

4 Aims and Organization

This volume responds to the need for a consolidated, interdisciplinary approach to the management and governance dimensions of water resilience for scholars, resource managers and policy makers. Four objectives guide this book on water resilience: (1) to capture current knowledge and understanding of management and governance in the context of water resilience; (2) to advance theory through synthesis of research and experiences from a variety of disciplinary perspectives; (3) to illuminate the implications of theory and experience for innovation in practice and policy; and, 4) to explore the frontiers of water resilience and set an agenda for future research.

This opening chapter of the volume introduced the subject of water resilience. It provides a rationale for the undertaking and also orients readers to scholarship upon which the contributors build. In so doing it provides a departure point for the chapters that follow.

As opposed to focusing on just one of the aforementioned objectives, the chapter contributors tend to address them in concert. That is, they build on present knowledge as well as draw upon research and applied experiences to advance theory, practice and policy. Moreover, the objective of giving voice to a variety of disciplinary perspectives emerged organically. All of the chapters in the volume are collaborative efforts, with most spanning one or more conventional disciplinary boundary. The diversity of perspectives and collaborative approach is indicative of this area of scholarship.

Contributors to the chapters engage with that vast and rich conceptual ground that needs to be considered in deepening knowledge relating to management and governance dimensions of water resilience. Cosens and Gunderson, for example, draw attention to legal aspects attendant for resilience and reconciliation. Transformations and transitions are focal constructs for Blythe, Armitage, Bennett, Silver and Song in their consideration and cautions about ocean governance. Trimble, Jacobi, Olivier, Zurbriggen, Pascual, Garrido and Mazzeo draw on the concept of anticipatory governance in relation to resilience.

Johannessen and Wamsler focus on social learning in governance that can accommodate the extraordinary era of the Anthropocene. Mirumachi, White and Kingsford use a conceptualization of five paradigms of water to explore governance over time in three major river basins. Others build upon established resilience scholarship and extend it new areas. Baird, Plummer, Quinlan, Moore and Krievins consider factors underpinning persistence, adaptive capacity and transformative capacity and their relationships in the watershed context. Reilly, Bennett, Adamowski and Hickey consider how resilience thinking can move management from a focus on the individual to collective action in agriculture.

The chapters in the volume strongly reflect the pertinence of water resilience worldwide and diverse circumstances of water management and governance. Contributors draw upon cases from Asia, Australia, Europe, North America, South America, and South Africa. The cases range considerably in size and focus. For example, from large transboundary river systems (e.g., Mekong, Columbia, Saint John) to small scale fisheries to urban centres. A fulsome variety of management and governance situations are also addressed. For example, Kochskämper and Newig examine experiences with the European Union Water Framework Directive. Marshall and Lobry de Bruyn identify a key role for non-governmental organizations in river basin governance in Australia. Roberts, Milman and Blomquist discuss challenges of bringing water resilience into existing governance approaches in California.

The final section is forward oriented and directs readers to future concerns and issues with water resilience. Integrating ideas and concepts as well as applied experiences are stressed with the necessity of moving to a new water paradigm. The final chapter synthesizes the salient ideas made by the various contributions in the volume and highlights directions for further research, implications for practice and considerations for policy.

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Part II
Examining Water Systems Through the Lens of Resilience

Water Policy and Governance in Transition: The EU Water Framework Directive

Elisa Kochskämper and Jens Newig

Abstract The 2000 EU Water Framework Directive (WFD) set a turning point in European water governance: mandated participatory planning substituted conventional top-down approaches, the ecology of aquatic environments became the WFD's focal point, and the river-basin scale was institutionalized as the central governance unit. In 2007, the Floods Directive – a 'daughter directive' to the WFD – incorporated aspects of resilience through flood risk management. The two directives attempted a transition towards a sustainable and resilient water governance system; however, almost two decades later, it remains unclear whether the directives were instrumental in fostering such a transition. We report on several case studies in European water governance. These highlight the complexities of furthering change towards sustainability: institutional adaptation towards the new governance modes was slow and mandated participatory planning not instrumental for ground-breaking results. The European experience shows that adding more governance does not automatically bring about fundamental change.

1 The Visionary Ambitions of the EU Water Framework and Floods Directive

With the new millennium, the EU Water Framework Directive (WFD Directive 2000/60/EC) set a turning point in European water governance: the European Member States were envisioned to harmonize and transform their water policy regimes by acknowledging the ecology of aquatic environments and by integrating all related water aspects holistically (Boeuf & Fritsch, 2016; Kaika, 2003; Voulvoulis, Arpon, & Giakoumis, 2017). The systemic approach is reflected in the

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embracement of integrated water resources management that focuses on the river basin as the main governance unit (Voulvoulis et al., 2017). The required river basin management (WFD, Art. 1) meant a shift from predominantly top-down structures of Member States towards decentralized governance arrangements (Woodhouse & Muller, 2017). The Directive's ambitious goal is to bring all European ground and surface waters into a predefined 'good' status in terms of quantity and quality until 2015 and no later than 2027 (Art. 1). In comparison to former, target-oriented environmental EU directives, the WFD puts stronger emphasis on proceduralization by introducing required policy instruments while affording considerable leeway in their implementation to Member States (Liefferink, Wiering, & Uitenboogaart, 2011). Based on this holistic approach with a focus on the river basin as the system of interest, the WFD was perceived as the first European directive targeting environmental sustainability (Carter, 2007; Johnson, 2012; Tippett, 2005) with the potential of a prototype for future directives (Josefsson, 2012).

The EU Floods Directive (FD 2007/60/EC), that came into force seven years later, clearly followed this approach, and was subsumed under the overall WFD framework as a daughter directive (European Communities [EC], 2009). The FD, attempting to enhance the protection of human health, the environment, cultural heritage and economic development from flooding events, is not exclusively addressing environmental sustainability. Different from the WFD, the overall goals of the FD are not linked to clear targets. Hence, an even stronger proceduralization lies at the core of the Directive. Both proceduralization and decentralisation can be seen as responses to deficits in the successful implementation of European environmental policies (Challies, Newig, Kochskämper, & Jager, 2017). A central policy approach that embraces the two concepts is mandated participatory planning (MPP) (Newig & Koontz, 2014). The participation of non-state actors or 'interested parties' as stated in the directives (WFD, Art. 14; FD, Art.10) is mandatory in their implementation. Having considerable leeway in how they implement participatory planning, Member States are required to ensure information supply and consultation while 'active involvement' in planning is only 'encouraged'. EU guidance documents, however, stress active participation "as a means to improve decision-making" (EC, 2003, p. 14) and to increase acceptance and thereby the delivery of decisions in WFD and FD implementation (EC, 2009). Such "proper implementation" (EC, 2009, p. 18) is seen as decisive to increase the resilience of European water systems.

All in all, it can be argued that the two directives attempted a transition towards a sustainable and resilient European water governance system. Nonetheless, almost two decades later, it remains unclear whether the directives were instrumental in fostering such a transition. Currently, 60% of all surface water bodies are not achieving good status; only 20% of them have improved their status, while the overall ecological status of surface water bodies has slightly worsened from 2009 to 2015 (EC, 2019). The Directive's overall effectiveness is therefore questioned (Boscheck, 2006; Moss, 2008), aggravated by the lack of evidence on the effects of the newly introduced policy instruments (Boeuf & Fritsch, 2016). Participation as the most studied topic of WFD scholarship represents a major example, since the link to ecological outcomes is largely neglected (ibid.; see Drazkiewicz, Challies, & Newig, 2015; Kochskämper, Challies, Newig, & Jager, 2018 as a notable exception). To establish convincing causal links between MPP and effective outcomes proves to be even more difficult in the FD context due to the absence of clearly defined objectives.

We ask whether MPP was implemented, or if the introduction of this new policy instrument into the European water governance regime has fallen short of the demanding ambitions of the directives. The remainder of this chapter is structured as follows: first, we describe MPP as a governance mode in the directives in detail and explain our methodological approach in bringing together the results of published and unpublished material. In the empirical part, we summarize WFD implementation efforts at the European level, before we engage with a range of European case studies. We proceed in a similar manner for FD implementation, first, at the level of German Federal States and then in two German case studies. Finally, we discuss whether the directives initiated a transition process in European water governance.

2 Mandated Participatory Planning as a New Approach of Proceduralization and Decentralisation

The participation of non-state actors has been a recurrent theme in water governance since the 1970s (Woodhouse & Muller, 2017). The integration of participation into the WFD represented an early application of the Aarhus Convention of 1998,[1] which grants the rights to access to information and public participation in environmental matters in ratifying countries. Participation is understood here as a three-dimensional concept, and can be more or less "intensive" in each of the following dimensions (see Newig, Challies, Jager, Kochskämper, & Adzersen, 2018): (1) *Breadth of involvement*: the range of stakeholders and other actors included in the process. (2) *Communication and collaboration*: the manner, direction, and intensity of information flows. (3) *Power delegation to participants*: the extent to which participants are afforded influence over the decisions to be taken.

In the directives' context, participation represents a policy instrument or governance mode, i.e. a strategic intervention that supports the achievement of a certain goal (Scott & Thomas, 2017). Participation can enhance the quality of environmental outcomes through environmental advocacy by newly included actors or relevant information brought in by different knowledge types (see Newig et al., 2018). Negotiation, dialogue, and deliberation can lead to the identification of mutual gains, learning and innovation, and a common good orientation (ibid.). Further, participants may accept decisions, built or strengthen capacities and networks,

[1] Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters.

which can ultimately smooth implementation of and support compliance to collective decisions (ibid.). Moreover, Sabel and Zeitlin (2008) argue that participation required by the WFD can be seen as an extension of transparency in European governance, since it allows for insights into deliberative mechanisms of problem solving and policy making.

The encouragement of participation is directly linked to integrated river basin management that embodies the WFD's systemic approach by recognizing the interactions and interdependencies of water systems with other physical and socio-economic systems (Voulvoulis et al., 2017). All Member States had to determine River Basin Districts (RBDs) in line with hydrological boundaries and define according Competent Authorities for WFD implementation. They first had to carry out an assessment of the current status of all water bodies in the RBD and designate water bodies into natural, heavily modified, and artificial. Significant pressures on the waters had to be identified and according measures produced and gathered in programmes of measures (PoMs WFD, Art.13) and river basin management plans (RBMPs WFD, Art.11). Those measures are decided on, implemented, and monitored within six-year policy cycles. Each cycle starts with a new water status assessment and the designation of water bodies, revealing potential improvements in water quantity and quality as well as advanced renaturalization. The first plans were prepared for 2009. The instrumental value of participation is assumed to show specifically in the development of PoMs and RBMPs (WFD, Art.14). The FD adopted the same procedural approach, merely with the difference that measures are not decided for the entire RBD but are restricted to areas with significant flood risk within the basin. Flood risk is once more assessed at the beginning of the policy cycle and documented in publicly available flood risk and hazard maps. Subsequently, flood risk management plans (FRMPs) are developed and measures implemented and monitored. Again, participation can be used during the whole policy cycle, but is particularly encouraged in the development of FRMPs (Art. 10). The WFD and FD share the same time intervals for their policy cycles with the first FRMPs developed by 2015, whereby the participatory planning of measures should be coordinated (Art. 9).

Participation is expected to enhance effectiveness in sustainable and resilient measures in both directives; yet, resilience is more pronounced in the FD. Without defining it further, the FD mentions resilience in the context of civil protection and preparedness. Preparedness is defined by the European Commission as "informing the population about flood risks and what to do in the event of a flood" (Commission of the European Communities [COEC], 2004, p. 3). Generally, the FD demonstrates a paradigm shift from flood protection to flood risk management (FRM) (Newig, Challies, Jager, & Kochskämper, 2014). In contrast to flood protection, which aims at controlling the flood hazard, FRM can be defined as the "continuous and holistic societal analysis, assessment and mitigation of flood risk" (Schanze, 2006, p. 233). According to European guidance, increasing knowledge of potential climate risks, knowledge exchange amongst key stakeholders, awareness raising, education and training enhance adaptive capacity, defined "as the ability to cope, adapt or recover from the effects of a hazard" (EC, 2009, p. 4). Additionally, active participation in

FRM can build a sense of shared responsibility between the administration and the wider public in the preparation to, dealing with and recovery from natural disasters (Comfort, 2005; Fazey et al., 2017; Gallopín, 2006).

Participation is serving a legitimizing and particularly instrumental function for sustainable and resilient European water governance, and is tightly entangled with the additional core policy instruments of river basin management in the WFD and flood risk management in the FD that demonstrate the new systemic and holistic governance paradigm envisioned by the EU. In the following, we will examine whether such a paradigm, which could pave the way for a comprehensive governance transition, actually emerged.

3 Methodology

For depicting a rich image of WFD and FD implementation and the use and effects of participatory governance here within, we integrate results of published and unpublished material. We start with WFD implementation, for which we summarize our results from the study of Jager et al. (2016) that assessed the extent to which river basin management and participation were introduced in 13 European Member States via a combination of qualitative and quantitative methods (document analysis, multi-dimensional coding system and an agglomerative cluster analysis). Subsequently, we go more in depth into eight cases of MPP in Germany, Spain and the UK, drawing on the qualitative comparative case study by Kochskämper et al. (2016, 2018). This analysis is based on 44 semi-structured, face-to-face interviews and a document analysis. We evaluated PoMs and RBMPs based on the extent to which measures targeted main anthropogenic pressures and their implementability (e.g. specificity of measures, identification of implementing addressees). In addition, we traced the status of implementation via the 2015 PoMs and RBMPs. We back up our own results with information by the most recent EU assessment on the implementation progress of the WFD (EC, 2019). For the FD context, we first give an overview of the implementation of MPP in German federal states. Then we dive into two cases of MPP in two neighbouring federal states. The case studies are based on a mixed-methods approach, comprising semi-structured interviews ($N = 16$), document analyses as well as an online survey (process and outcome variables on a 4-point Likert scale: 1 [not at all], …, 4 [completely]) of participants ($N = 29$) conducted in 2017.

4 The Transition Process Towards Sustainable Water Governance Through Water Framework Directive Implementation

By the start of the first WFD policy cycle in 2009, all 13 Member States complied with establishing River Basin Districts (RBDs) as the main governance unit. Four countries (Austria, Denmark, Germany, Scotland) complied exclusively with the legal minimum of delineating RBDs. Apart from Sweden that went from no river basin management to a complete adoption of the approach, the majority of countries drew on existing structures: some already had followed river basin management with formally responsible institutions, and several displayed features of the approach, which they did not strengthen further.

About half of all European Member States opted for assigning Competent Authorities at different governance levels and not only at the RBD but mainly the regional level (EC, 2019). This opened up an intricate multi-level structure for producing RBMPs as the main vehicle for river basin management (see Newig & Koontz, 2014), particularly in cases such as Germany, where RBDs match hydrological units, while the Competent Authorities reflect administrative boundaries. The multi-layered coordination needed was eased by the leeway afforded to Competent Authorities that included the option to produce sub-plans to RBMPs, which more than one-third of Member States made use of (ibid.). The emphasis on pre-existing governance structures in the 13 observed countries conveys a rather cautious institutional adaptation towards the new governance mode of river basin management. Apparently, however, coordination among and within RBDs has been strengthened during the second WFD policy cycle starting 2009 (ibid.).

Compared to river basin management, participatory planning showed a higher degree of institutionalization. All 13 Member States engaged with participatory planning at the RBD level and, except for one (Denmark), intensified the degree of participation they used before WFD adoption (Jager et al., 2016). We selected three Member States from our sample to examine the adopted designs and effects of participation in WFD implementation more in depth. To gain a deep understanding of cases showcasing mandated participatory planning (MPP), we selected countries with the most diversity in approaches, drawing on the three dimensions presented in Sect. 2 (see Kochskämper et al., 2016, 2018). Due to the option of sub-plans the most decisive level of decision-making for RBMPs could be frequently encountered at the sub-basin level. The case selection led to eight cases at the sub-basin level in Germany, Spain and the UK, with three 'more' and three 'less' participatory cases in each country (in the UK in Scotland and Northern Ireland), and two cases laying in between on this continuum in Germany and in Spain.

In all of the cases the physical alteration of water flows through infrastructure such as dams, and channels represented a significant anthropogenic pressure, particularly in Germany with up to 91% of water bodies being heavily modified or artificial in the 'in-between' case, and in the 'less participatory case' in the South of Spain with 77% of non-natural water bodies as a consequence to extensive irrigation of water intensive crops. Impacts stemming from agriculture were the paramount pressure on the waters in the majority of cases, for instance through agrochemical contamination and frequently through pollution via nitrate entries as a result of intensive livestock farming, for which the German cases are a major example. This might also explain the overall poor water status in the German cases, with 13% of water bodies in a good status in the 'less participatory' case, and only one in the 'more participatory' case and none in a good status in the 'in-between' one. The number is also fairly low in the Northern Ireland case with 3%. The Scottish case displayed 22% in a good status and this number ranges from 33% to 41% in the Spanish cases. The pressures of distorted hydromorphology (through e.g. physical alterations) and diffuse source pollution - particularly through agriculture -, continue to present the foremost challenges for all European Member States in the second WFD cycle, apart from atmospheric deposition (EC, 2019, p. 61).

Below, we describe first the participatory designs and afterwards their actual realization. The design of participatory decision-making processes varied substantially across the cases (see Table 1). The 'more participatory' case in Germany opted for a small working group comprised by eight carefully selected stakeholders that met mainly monthly. The 'in-between' case formed a so-called area co-operation with 23 stakeholder representatives holding two to five meetings per year, and the 'less participatory' case a regional water forum with 65–90 participants that came together annually. In contrast to Germany, all meetings were open to the wider public in the 'more participatory' and the 'in-between' Spanish cases. The Spanish cases followed all a similar approach with so-called sectoral meetings for different stakeholder groups and multi-stakeholder forums. In the former, information events were held throughout the basin to activate citizens, and in the latter the events were promoted even in bars and churches. This culminated in a total of 150 and 644 participants respectively attending 15 and 14 meetings per case. In the 'less participatory' Spanish case two meetings with a maximum of 50 participants took place. The 'less participatory' case in Northern Ireland formed a so-called catchment stakeholder group that was also open to the wider public. In general, 20–30 stakeholders and citizens participated in bi-annual meetings. Eventually, the 'more participatory'

Table 1 Eight observed cases of mandated participatory planning

Degree of participation	Germany	Spain	UK
'More'	Working group (8 selected local stakeholders)	Sectoral and multi-stakeholder meetings (155 stakeholders and citizens)	Scottish area advisory group (15–25 invited key stakeholders)
'In-between'	Area co-operation (23 selected stakeholders)	Sectoral and multi-stakeholder meetings, water forums (644 stakeholders and citizens)	
'Less'	Regional water forum (65–90 invited stakeholders)	Sectoral and multi-stakeholder meetings (50 invited stakeholders)	Northern Ireland catchment stakeholder group (20–30 stakeholders and citizens)

UK case in Scotland created a so-called area advisory group that targeted key stakeholders already experienced in water management that comprised 15–25 participants meeting bi-annually. In all cases the set of stakeholders was diverse; environmental groups were always at the table together with representatives from agriculture, industry, forestry, angling, and municipalities among others. This is in line with latest EU observations finding that on average more than seven types of stakeholder groups (also e.g. energy/hydropower or water supply and sanitation; seldom universities and research centres) participated actively throughout the RBDs of European Member States (EC, 2019, p. 40).

The actual course of participatory processes played out rather differently in our cases: in the three 'less participatory' cases the communication mode centred on information provision by the administration with limited consultation or discussion. The other two Spanish cases showed instead a mutual information flow between the administrative and participant side. The agencies organizing those processes represented newly elected administration with high motivation and expectation towards the WFD's approach that mirrored the paradigm of a 'new water culture' (Hernández-Mora & Ballester, 2011). This had emerged in opposition to national plans at the beginning of the 2000s to continue with massive water transfers without considerations of ecological or social contexts. The organizers put effort in a fair voicing of all opinions and considerations, which could not flourish into dialogue or deliberation due to the process design and the sheer amount of participants. The Scottish area advisory group drew on a network approach through consulting the key stakeholders on projects already existing on the ground, bringing together and strengthening administrative and stakeholder efforts within the planning documents. Only in the small German working group a constant dialogue on measures appears to have taken place within an atmosphere perceived trustful and productive by participants. This also seemed to happen in the German area co-operation at the beginning, but was disrupted by a disagreement between administration and stakeholders on potential financial contributions to decided-on measures by stakeholders, which hamstringed the whole process.

So, what did these different trajectories of MPP mean for the advancement of sustainable European water governance? We separated results into a participatory and a political output, since in the 'less participatory' and 'in-between' cases it was not possible to draw a clear connection between the participatory input provided and final planning documents developed. Only the 'more participatory' cases showed a clear connection between the input stemming from participatory processes and the PoMs and RBMPs or sub-plans. We analysed all political and participatory outputs that we were able to trace (six). Participatory outputs performed generally well in terms of measures targeting the main anthropogenic pressures of the sub-basins. However, in the German working group alterations in water flows were effectively addressed but measures tackling diffuse pollution by agriculture were left out entirely. While participatory outputs in Spain characterized very high, perhaps unrealistic, expectations on the part of participating stakeholders, the overall accurate suggestions to addressing main water pressures were not reflected in the final planning documents of both the 'in-between' and the 'less participatory' case.

In the cases with no clear connection of participatory input or traceable output (the catchment stakeholder group in Northern Ireland, regional forum, and area co-operation in Germany) the political output targeted the main pressures with according measures. However, the implementability or feasibility of those seemed not very high, as implementation in Germany depended on the financial contribution by stakeholders in the area co-operation, which had already caused a heated conflict during the process, or on a voluntary principle for all measures addressing agriculture in the case of the regional forum. The catchment stakeholder group in the UK produced sub-plans with almost entirely soft and generic measures, such as further investigation or assessments. As all examined planning documents were produced for 2009, we could scrutinize the implementation status after the first WFD cycle. In the three latter cases (area co-operation, regional forum, catchment stakeholder group) implementation was rather low. No advances in implementation could be found for all three Spanish cases, which in the 'more participatory' and 'in-between' case might be explained by changes in the administration after the financial crisis affecting particularly Southern Europe in 2009. Only the network approach in the Scottish area advisory group and the consensus-based working group style in the 'more participatory' German case seemed to enable a comprehensive implementation of measures.

The observed implementation gap presents a common drawback for all European Member States, as up until now only in 8% of RBDs measures of the first PoMs have been completed, whereas in the vast majority of 84% of RBDs only some measures have been concluded (EC, 2019, p. 182). The three main reported reasons by Member States were lack of finance (79%), unexpected planning delays (72%), and governance issues such as the lacking adoption of national regulations (50%) (ibid., p. 183). Not even half of RBDs have reported that financing is secured for the implementation of the second PoMs, and in five Member States, among them Spain and the UK, financing had not been secured for measures in any sector (ibid.). The first assessment of RBMPs and PoMs by the EU showed a limited understanding that measures had to reflect main pressures by providing indications of how specific problems of water bodies would be tackled (ibid.). The listed measures were frequently vague, without clarity on their scope, the timing for implementation, financial commitment or actors responsible for implementation (ibid.). Most Member States improved in this respect in the second RBMPs by strengthening the link between water status, pressures, and according measures, but only few Member States have reported such an analysis thoroughly. According to the EU assessment, the sharing of information on methodologies between and within Member States would support this analysis for the implementation of the third PoMs substantially (ibid.). One area with particularly little progress is diffuse source pollution by agriculture, where many measures are voluntary in nature, such as in the case of the German regional forum, potentially hindering progress in implementation when the uptake by farmers remains low (ibid.).

5 The Transition Process Towards Resilient Water Governance Through Floods Directive Implementation

As a daughter directive to the WFD, the Floods Directive (FD) reflects the systemic approach which centres on areas with significant flood risk in river basins, as well as flood risk management (FRM). Moreover, the Directive promotes natural protection measures (e.g. floodplains), preferably designed in coordination with the WFD. Similarly, the involvement of stakeholders as a vital policy instrument is encouraged to be aligned with mandated participatory planning (MPP) under the WFD. In the following we examine briefly the context of German federal states that are the Competent Authorities for the Directive's implementation. Prior to the FD, FRM was largely absent in the planning of federal states, apart from first tendencies after major floods during the 1990s and early 2000s (Newig et al., 2016). Flood security characterized the main planning paradigm (Hartmann & Spit, 2016) in seeking to increase defence measures in the aftermath of flood events. The federal states share implementation responsibility with municipalities which are the main actors for the planning and operationalization of measures at the local level, and responsible during a crisis situation. Many of them rely on volunteer structures for these events, such as volunteer fire brigades. Usually flood risk and hazard maps were developed at the federal state level through the environmental ministries (Newig et al., 2016). The national level issues guidance documents for developing FRMPs through the inter-state working group on water (LAWA – *Länderarbeitsgemeinschaft Wasser*). LAWA guidelines foreshadowed the FD on many issues, such as natural protection measures and flood action plans but made no provisions for active participation.

The Directive initially caused resentment by federal states, as they were afraid of too strict regulations and disapproved the close alignment of WFD and FD implementation due to – according to them – different actors and interests involved in the two policy fields (Newig et al., 2014). The alignment of participatory processes during the first FD cycle with the ones installed under the WFD was not commonly pursued (six federal states) (ibid.). Five federal states engaged into participatory efforts that met the bare legal minimum through information provision and consultation on final draft FRMPS. Three federal states stood out as counterexamples, as they used so-called flood partnerships in the form of multi-stakeholder forums also open to the wider public. This breadth of involvement stands in contrast to the general trend of reduced opportunities for citizens to access FD participatory processes in comparison to the WFD context (ibid.). German WFD processes usually addressed representatives of organized interests and rarely citizens. The involvement of citizens remained therefore very limited for the FD.

Two different approaches to MPP can be found in *Baden-Württemberg* (BW) and *Bavaria* (BA), where we zoom in on the river Iller that forms the administrative border between these two most southern federal states. The river descends from the Alps and discharges after 147 km into the Danube, constituting an area of significant flood risk. *Baden-Württemberg* is the federal state in which the concept of flood partnerships originated. They function as a connecting mechanism between municipalities within the same river basin (Fortbildungsgesells für Gewässerentwicklung [WBW], 2012) to activate their engagement in planning as well as raising and maintaining flood risk awareness (Interview Ministry of the Environment, Baden-Württemberg). Flood partnerships are not organized by the federal states as Competent Authorities or the district governments as their representation, but a non-profit company for education in water development (*WBW Fortbildungsgesellschaft für Gewässerentwicklung,* WBW), appointed by the federal states' ministry of the environment.

The flood partnership we examined was installed in 2009 (flood partnership 18 – Riß/Rot/Iller) and met four times. In total, 66 municipalities adjacent to the river Iller are invited to take part and according to a municipality representative usually 30–40 municipalities attended the meetings. Additional invited stakeholders are the district administration (3), private sector (4), disaster control organizations (2), water associations (2), the State Institute for the Environment, and a regional planning association. According to the ministry interviewee, the lacking participation by representatives of agriculture and environmental groups or citizens in the flood partnership mirrors a common tendency throughout the federal state. Multiple interviewees stated that public officials, municipalities and private actor representatives all agree on low flood risk awareness among citizens that have not experienced recent flood events. According to one governmental interviewee, citizens lack the knowledge or interest to contribute to planning ("[They] do not care about the development of emergency plans"), as their main interest is the protection of own property. The interviewee perceives agriculture and environmental groups as not having main stakes. According to another interviewee, ENGOs highly active in WFD implementation did not follow invitations to the meetings; however, they collaborate with the WBW, which shares their positions on increased natural protection measures. Most participants of the survey we conducted perceive a balanced representation of stakes in the current FRM approach (36% mainly, 27% completely). Nonetheless, no ENGOs participated in the survey and a municipality sees the stakes of nature conservation and agriculture as missing.

The flood partnership started with plausibility checks of flood risk and hazard maps, which some interviewed stakeholders found too demanding to conduct due to underlying hydrological technicalities. Questionnaires were sent to the municipalities to gather information about their current FRM status, to present afterwards all measures possible based on LAWA guidance and developed by the ministry of the environment (interview government district). Municipalities could select measures and had to indicate the estimated year of completion. According to the process chair (WBW) and several participants (municipalities, insurance) the meetings follow a relatively classical lecture style and are mostly used to provide information to municipalities, which seldom give input or ask for a specific topic to be discussed. A second part of the event during evenings is open to the general public. Stakeholders praise the meetings' organization as "perfect" (interview municipality) and "nothing to be criticized" (interview insurance). The survey responses corroborate this positive picture: the discourse is perceived as constructive [Mean = 3], rational

[3.3], and fair [3.3], and process moderation as satisfactory [3]. They perceive actual own influence on the results for FRM [2.4], which they found adequate [2.5], and also learned individually [2.9]. While the interviewed municipalities see meetings as an important tool for exchanging experiences, "further coordinated action" as a result of the meetings was rare.

The FRMP lists the measures the municipalities adjacent to the river Iller selected for implementation (Regierungspräsidium Tübingen [RPT], 2013). In general, flood defence infrastructure is already in place, and 20% of municipalities want to extend or update its maintenance. Flood control measures were not the dominant selected measure type by municipalities in comparison to mitigation measures such as updating or developing emergency plans, planned by all municipalities. Emergency plans are required by law since 2012 as the main coordination instrument between fire brigades and municipalities. Regarding preparedness, 82% of municipalities plan to provide information for the population and enterprises, 18% have this already in place, and only 9% already provide information and requirements under building permits. No additional municipality selected the latter measure, and no municipality opted for the introduction of a web-based, improved information system that seeks to foster information dissemination and networking before a crisis situation. Nevertheless, the introduction of information for the wider public seems an important step; according to the process chair a lot of municipalities use the same means to provide information "as they were using 30 years ago", and the dissemination of knowledge by municipalities obtained in the flood partnerships to their own communities is largely absent. Natural protection measures are no listed in the FRMP, although there is a project in place that enhances natural retention areas, which falls under the responsibility of the water department of the district government.

Contrary to the institutionalized communication approach in *Baden-Württemberg*, Bavaria uses mainly informal channels of communication with municipalities through the multi-level water administration in FRM. Local water agencies and county administrative boards support and advice the municipalities by developing flood risk and hazards maps and draft FRM measures from which they can select, and which are later on aggregated into the FRMPs (Bayrisches Staatsministerium für Umwelt und Verbraucherschutz [STMUV], 2014). The ministry interviewee perceives again municipalities as the most important actors with main stakes. Additional stakeholder groups have been involved in FRM planning via an online tool through which proposals could be submitted (STMUV, 2014): fishery (1), tourism (4), water development (2), industry and commerce (7), municipalities (3), disaster control and security (11), sensitive infrastructure (8), preservation order (3), agriculture and forestry (5), environment and nature conservation (6), water services (2), shipping (4), hydroelectric power (3), churches, home owners, insurances (5) (Bayrisches Landesmat für Umwelt [BLU], 2014). The ministry interviewee values input particularly by associations such as fire brigades and civil protection that proposed measures, based on their local knowledge and experience, that would not have been considered otherwise. Proposals by environmental groups are perceived by the same interviewee as frequently ideological (against technical measures) and demands by agriculture rather extreme. The farmers' association representative criticizes that their opinions expressed in the online tool have not been further integrated into the planning process. The survey participants perceive that important stakes are missing at all (26%) or to some extent (44%) in the current FRM approach, such as natural FRM and biodiversity, agriculture, downstream inhabitants and citizens. All interviewees (lower water authority, municipalities, civil protection) agree on low risk awareness among citizens that do not own private property close to the river. The farmers' association representative criticizes the large amount of technical information in the current approach, which is difficult to digest and hinders citizens to inform themselves about flood risk.

In addition to the online tool and bilateral contact to the municipalities the governing districts in Bavaria organized kick-off events to inform municipalities and associations about FD implementation. Usually, municipalities affected by flood risk participated according to the ministry interviewee. Municipalities also had to report their current status of FRM measures. The majority of survey participants perceive that the informal participation structure only offers open exchange and dialogue to some extent (57%). However, when there had been dialogue and discussion, the discourse has been assessed as constructive, rational, and fair as in *Baden-Württemberg*, as well as the satisfaction with this communication, the results, and own influence [all mean scores only vary between −0.3 and + 0.4]. The only social outcome that is substantially lower is individual learning [Mean = 2.2].

In the FRMP (STMUV, 2015) the majority of measures are defence measures, predominantly the maintenance and control of existing infrastructures, selected by 75–100% of municipalities (numbers are not depicted more precisely in the FRMP). Natural retention in urban areas is planned by 75–100%, and the designation of flood plains by 25–50% of municipalities. Regarding preparedness measures, 75–100% of municipalities mainly targeted improved information and warning systems, and 50–75% of municipalities want to engage into flood risk education, and the same amount is planning to develop emergency plans.

While the Bavarian municipalities continued with a strong focus on flood security, it seems that in both cases municipalities were encouraged through participatory planning to decide for mitigation measures in line with FRM. However, whether this was caused by MPP or legal obligations and LAWA guidance is not clearly discernible. Irrespective of the MPP style, municipalities in both cases studies adopted preparedness measures for informing and educating the wider public, and in Bavaria moreover natural protection alternatives. Emphasis on stakeholders already active in the field and rather technical planning prevailed in both cases. The only difference between the participatory styles which could be clearly identified is substantially higher individual learning in the flood partnership model of *Baden-Württemberg*.

6 Transition of European Water Governance: How Far Have We Come?

Departing from former exclusively target-oriented approaches, the Water Framework and Floods Directive (WFD, FD) introduced decentralising, procedural policy instruments to advance sustainable and resilient water governance throughout the EU, allowing for flexibility in their implementation. European Member States were pulled away from top-down governance structures towards governance arrangements that acknowledge systems delineated by hydrological boundaries, interacting with other (sub)systems, and impacted by disturbances such as floods. However, the evidence presented in this chapter shows that Member States were fairly hesitant to adopt this systemic paradigm.

River basin management was introduced by all Member States, which rarely altered their governance structures substantially. In contrast, mandated participatory planning (MPP) led Member States to draw from a diverse palette of possible process designs. However, the high expectations in the instrumental value of participation appear not to be met: only in two out of our eight WFD cases, participatory planning actually led to a high standard of measures and comprehensive implementation. In one of these cases measures targeting agriculture as one of the main causes for poor water quality were not agreed upon for the sake of feasibility (Kochskämper et al., 2018). Also in the remaining cases and European Member States, generally the resistance to address agricultural contamination is a major drawback for WFD implementation (ibid.; EC, 2019). Tendencies to implement measures that do not readily address pressures represented an overall trend; participatory outputs performed here well, but were not always taken into consideration for final, political outputs. While participatory outputs might not have been realistic in some cases, this can also indicate continuity in the use of centralized, administrative decision-making (Voulvoulis et al., 2017). According to Voulvoulis et al. (2017) "the lack of real change enabling a fundamental shift towards system thinking could be seen as the underlying cause" for such obstacles to WFD implementation (p. 363).

Similarly, with regards to the FD, the technical flood security paradigm seems to prevail in Germany, as the reliance on mainly defence measures or on stakeholders traditionally active in the field shows. However, municipalities in both cases introduced mitigation and preparedness measures representative for resilient flood risk management as a result of participation. In the flood partnership comparatively more municipalities than in the Bavarian case introduced emergency plans, which might be essentially the impact of legal regulatory requirements in *Baden-Württemberg*. This raises the question whether the procedural approach of the directives, which allows for a lot of flexibility of Competent Authorities in implementation, is alone, without further, enforceable obligations, sufficient for effective outcomes – which constitutes already a debate in the WFD context (van Rijswick & Backes, 2015).

Nonetheless, in both FD cases increased information provision for the wider public and other stakeholders is planned, which appeared to have been absent in their flood risk management beforehand. This might be a first step towards enhanced activation of citizens in participatory planning; in both cases their flood risk awareness is far from the ideal of developing adaptive capacity. Debatable in this context is the necessity of active involvement versus transparent and understandable information provision on decided-on measures (see Sabel & Zeitlin, 2008). In general, planned improved information dissemination and the integration of formerly not involved actor groups are major advances under FD and WFD implementation. Participation did in this sense foster transparency in policy making. Moreover, natural protection measures were introduced either under the FD or WFD umbrella in our case studies, and the targeting of main anthropogenic pressures on waters has improved according to EU evaluations.

The latter development can be seen as an opportunity for and cautious development of governance learning (Challies et al., 2017; Newig et al., 2016) supported by the cyclical approach of the directives. The exchange of assessment methodologies and coordination in participatory processes as proposed by the EU could aid this endeavor. Learning from feedback in the light of uncertainty and change catalyzes adaptive capacity and resilience in complex systems (Plummer, Armitage, & de Loë, 2013) as embodied by the European water governance regime. The case studies presented in this chapter show a more nuanced picture of participation than the EU assessments, which might be an argument to involve the scientific community stronger into such evaluations.

All in all, the visionary ambitions by adding more governance through procedural policy instruments are not met by the degree of policy transition, exemplified by the remaining implementation gap of WFD measures and the restrained embracement of flood risk management in FD implementation. Progress appears to happen; however, after almost two decades in place the directives did not bring about fundamental change or paradigm shifts.

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The Sustainable Groundwater Management Act (SGMA): California's Prescription for Common Challenges of Groundwater Governance

Michael Roberts, Anita Milman, and William Blomquist

Abstract Reducing and reversing current trends of groundwater depletion will require development of resilient systems for groundwater governance. Yet establishment of such systems requires overcoming common conundrums of groundwater governance including: organizing and enhancing governance structures, incorporating diverse interests and uses of groundwater, and using science in-formed adaptive management. In 2014, with passage of the Sustainable Groundwater Management Act (SGMA), California implemented a novel approach to groundwater governance. SGMA devolves both authority and responsibility for achieving sustainable groundwater management to the local-level yet includes the threat of state-level intervention when the local-level does not comply with legislative and regulatory requirements. This system of multi-level governance seeks to balance preferences for local-level control with the need to address groundwater use and impacts at the basin-level. This chapter reviews the groundwater management in California leading up to SGMA, describes the approach to groundwater governance set forth in SGMA, and provides an initial assessment of the early stages of implementation of SGMA. In doing so, the chapter situates SGMA in the theoretical literature on groundwater governance. Lastly, this chapter provides insights as to the factors that may make the approach adopted by SGMA effective, if such a system is to be adopted elsewhere.

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1 Governing Groundwater—A Global Conundrum

Intensive use of groundwater has led to what some are calling a "global groundwater crisis" (Alley & Alley, 2017; Famiglietti, 2014; Thomas & Gibbons, 2018). Throughout the United States and the rest of the world, groundwater resources are immensely important, supplying 50% of human drinking water and half of the irrigation water used to grow food (Siebert et al., 2010). Groundwater resources also support ecosystems and are critical for managing the temporal variation in surface water availability. In many regions, groundwater abstraction has resulted in groundwater depletion (Castilla-Rho, Rojas, Anderson, Holley, & Mariethoz, 2019; Konikow & Kendy, 2005; Tracy et al., 2019; Wada et al., 2010), causing lower groundwater levels, reduction in groundwater storage, salt-water intrusion, degraded water quality, land subsidence, and impacts on interconnected surface waters.

The United Nations, the Organization for Economic Cooperation and Development, academics, and many practitioners have concluded that current rates of depletions are largely due to a failure in governance (Foster, Chilton, Nijsten, & Richts, 2013; United Nations Educational, Scientific and Cultural Organization [UNESCO] & Books, 2003). Governance includes the full set of organizations, structures, rules, and processes that enable collective action to occur (Lemos & Agrawal, 2006). Management refers to the specific policies and decisions that guide day-to-day actions influencing water. Governance is a predecessor to and sets up the framework through which management is decided and acted upon. Thus, the failure of groundwater governance is in essence a failure of the systems that enable decisions to be made, actions taken, and policies enforced.

Globally, groundwater is governed poorly or not at all (Foster et al., 2013; Hoogesteger & Wester, 2015; Sagala & Smith, 2008). Where existing mechanisms for governing groundwater have been ineffective or are non-existent, new governance systems will need to be put in place (Molle & Closas, 2017). As explained below, reforming existing or developing new systems for groundwater governance is far from simple (Mukherji & Shah, 2005; Theesfeld, 2010). Furthermore, for new or reformed systems of governance to persist and to support water resilience, they will need to adapt to uncertainty and ever-changing conditions (Rockström et al., 2014).

The state of California is one place where the struggle to effectively govern groundwater has been particularly visible. California is home to 39 million people and the sixth largest economy in the world. Across the state, groundwater provides between 38 and 46% of annual freshwater supply, with the majority being used for agriculture (Department of Water Resources [DWR], 2013). In drought years, groundwater supplies the majority of water used in the state. Across the state there are as many as two million wells (DWR, 2019c). Prior to 2014, California could be considered a microcosm of the global groundwater conundrum in that state-level attempts to govern groundwater met substantial political resistance, and the modest state policies and programs that were adopted generated tepid local responses at best. Finally, in 2014 during an extended drought, the California legislature passed the Sustainable Groundwater Management Act (SGMA) (State of California, 2014), which directly seeks to confront many of the challenges intrinsic to groundwater governance.

This chapter examines the structure of SGMA and explains how it serves as a potentially promising alternative to prior approaches for groundwater governance. In doing so, we highlight common challenges for groundwater governance and how SGMA seeks to overcome them. We also illuminate how contextual factors, including support for implementation of SGMA by state and non-governmental actors, serve to alleviate some of the potential challenges of the governance structures created by SGMA. Combined, these findings shed light on factors that will be important for other regions seeking to follow California's novel approach to multi-level groundwater governance to consider.

2 Challenges of Groundwater Governance

The physical complexity of groundwater combined with the fact that it is a shared resource, used by diverse and dispersed interests, makes groundwater particularly challenging to govern (Alley, Reilly, & Franke, 1999). First, groundwater is invisible - it flows below the land surface and is generally only measurable at discrete points. In addition to its invisibility, groundwater is abstracted widely and by dispersed users. Groundwater is subtractable, such that pumping in one location impacts flows and availability in others (Bredehoeft, 2005). Adding to its complexity, groundwater is constantly in motion, and thus characterized by flows rather than stocks. These flows vary both due to the stochastic nature of the hydrologic cycle as well as heterogeneity of the subsurface through which it flows (Burke, Sauveplane, & Moench, 1999). Consequently, there can be a time lag between when groundwater is abstracted and when impacts of abstraction are experienced (Burke et al., 1999; Hugman, Stigter, & Monteiro, 2013). Lastly, multiple interconnected attributes of groundwater systems are important to human and ecological systems, including water levels, quality, storage, impacts on interconnected surface waters, and land-surface stability (subsidence) (Margat & van der Gun, 2013; Theesfeld, 2010).

Groundwater's physical properties provide an impetus for users to deplete the resource and set the stage for disagreement across users as well as those affected by impacts of groundwater use (Hoogesteger & Wester, 2015). Its invisibility complicates monitoring and enforcement of use. Its subtractability increases the potential for conflict across users. The heterogeneity of the aquifer and stochasticity of inflows and outflows increase uncertainty and require greater technical capacity needed to evaluate quantities of water available and to assess impacts of groundwater use (Theesfeld, 2010). Further, the interconnected attributes of the groundwater system means governance requires planning and managing for multiple objectives (Kiparsky et al., 2016; Milman & Scott, 2010). Effective governance of groundwater thus requires development of mechanisms that account for groundwater's physical complexity as well as groundwater's multiple uses and the interests of those who use or are affected by extraction. How to best achieve effective governance has been a topic of scholarly interest for decades (see e.g., Burke et al., 1999; Clark, 1978; Megdal, Gerlak, Varady, & Huang, 2015; Varady, Zuniga-Teran, Gerlak, & Megdal, 2016). The multitude of groundwater problems around the world indicates that development of such mechanisms is not straightforward and will require a departure from status quo paradigms of water governance. Given existing groundwater problems need to be addressed in an uncertain and changing world, groundwater governance systems will need to be resilient (Rockström et al., 2014; Plummer & Baird, this volume).

The attributes of water governance systems that promote resiliency are a topic of ongoing enquiry (Rodina, 2019). Chapter one of this book summarizes many of the attributes and practices of water governance systems that help to enhance resilience (Plummer & Baird, this volume); yet how to create new governance systems for groundwater that have these characteristics remains a conundrum. In particular, and as described below, creating groundwater governance systems with the attributes described in Chapter one entails resolving many challenges. Specifically, these include establishing governance structures that are both self-organizing and polycentric; ensuring inclusive participation and building shared understanding; and creating systems that are adaptive, evaluate risks, and address a wide range of ecosystem services (Doremus & Hanemann, 2008). Before examining how SGMA addresses these challenges, and thus represents a departure from prior, failed attempts to govern groundwater in California, we further define how the challenges introduced above stymie resilient groundwater governance and management.

2.1 Organizing and Enhancing Governance Structures

Resilient water governance relies on there being polycentric networks of institutions that are both flexible and adaptive across multiple scales and boundaries (Plummer et al., 2014). Moreover, institutions with the authority, jurisdiction, and capacity to develop and implement policies and management are essential (Kiparsky et al., 2016). However, designing resilient governance structures for groundwater is no small undertaking.

Where some groundwater management capacity exists at any particular location, the governance challenge is determining whether to strengthen the capacities of existing jurisdictions or to create new jurisdictions and fit them in with the array of existing authorities. Where no groundwater management capacity exists, new institutions must be created. In either case, a central concern is matching capacity to the physical conditions of a basin and the set of management needs. There are contrasting advantages to governance of groundwater at differing levels and spatial extents. Governance at the local level can facilitate incorporation of place-specific knowledge; monitoring and sanctioning; accountability of the governance system; and participation and support from groundwater users (Blomquist & Schlager, 2005;

Hoogesteger & Wester, 2015; Ostrom, 1990). Yet, local level governance may be subject to pressures from local interest groups and have less access to the knowledge, resources, and administrative capacities needed for management (Larson & Soto, 2008; Olsson & Andersson, 2007). Governance at higher levels has the advantage of separation from local-level politics, the ability to reduce potential externalities occurring across local-levels, and often includes access to greater capacities and resources. However, top-down arrangements for governance across a groundwater basin can generate political opposition due to local-level concerns about change, fairness, and potential inefficiencies (Ashley & Smith, 1999; Hoogesteger & Wester, 2015) and larger-scale institutions may have their own problems of interest influence (Lebel, Po, & Masao, 2005).

Closely related, is the question of geographic boundaries. Governance at the basin-scale allows for developing understandings of and managing the implications of use across the groundwater system as a whole, including avoiding conflicting actions (externalities) arising from poor coordination or disparate interests (Chermak, Patrick, & Brookshire, 2005). Yet basin-wide governance can involve significant transaction costs (Huitema & Meijerink, 2010) and it is difficult to devise rules effective across the full variety of interests and circumstances in a basin (Blomquist & Schlager, 2005; Olsson & Andersson, 2007). These tradeoffs mean that a common challenge to achieving resilient groundwater governance is developing institutional arrangements that best fit the policy-shed and the problem-shed (Davidson & de Loë, 2014; Foster et al., 2013).

2.2 Incorporating Diverse Interests and Values

Resilient water governance involves the full inclusion of diverse perspectives and actors throughout the decision-making and planning process (Plummer et al., 2014). As described above, the physical properties of groundwater, including the dispersed nature of groundwater use and impacts and challenges of monitoring flows and abstractions, makes it especially challenging to consider the breadth of actors who have control over or will be impacted by groundwater use. Across the globe there are countless examples of when politics and/or the failure to incorporate the diversity of water users has undermined groundwater governance (e.g., see for example the special issue of the journal Water Alternatives edited by Molle et al., 2018). This diversity includes differences among direct users of groundwater supplies (i.e., the pumpers themselves); differences with regard to both the quality and quantity of groundwater needed and the impacts of users on groundwater quality; differences in perceptions and valuations of impacts on interconnected surface water, habitat and other ecosystem needs; and differences in views on how to balance use of groundwater today versus using it as a storage reservoir for tomorrow. Consideration of the full spectrum of interests and needs leads to increased support for policies and can reduce the potential for future conflicts (Buizer, Jacobs, & Cash, 2010; Foster, Garduño, Tuinhof, & Tovey, 2009; Jacobs et al., 2010). While active efforts to engage stakeholders and promote participation have been championed throughout the policy literature (Carr, 2015; Koontz & Johnson, 2004; Organization for Economic Cooperation and Development [OECD], 2015), a major challenge to achieving resilient groundwater governance is incorporating the perspectives of multiple water users and uses, values and interests, in policy and management decisions.

2.3 Using Science-Informed Adaptive Management

The ability of policy-makers and managers to adjust decision-making through an iterative process is critical to designing resilient systems of water governance (Clarvis, Allen, & Hannah, 2014). Adaptive management, also described as "learning by doing" in Chapter one of this book, thus seeks a balance between accessing reliable and timely information with needing to make decisions under uncertainty (Plummer & Baird, this volume; Plummer et al., 2014). As described earlier in this section, substantial information and technical expertise is needed to understand groundwater flows and to predict the impacts of groundwater use in order to adaptively manage the multiple attributes of a particular groundwater system. In many, if not most, groundwater systems, an information deficit impedes the ability to take action (Mukherji & Shah, 2005; Theesfeld, 2010). Insufficient data on hydro-geologic properties; recharge pathways; historic water levels, withdrawals, and hydro-climatic conditions; and socio-economic conditions creates uncertainty and prevents future planning (Moench, 2004; Varady et al., 2016). Further, a lack of understanding of interconnections across the groundwater system (e.g., between groundwater quality and quantity, groundwater and surface water, water levels and subsidence, etc.) often means groundwater management focuses on specific, localized actions or effects (e.g., well spacing or an area of poor groundwater quality), rather than the system as a whole. Water management outcomes are highly correlated with goal specificity (Koontz & Newig, 2014), thus a challenge for groundwater governance is to develop science-informed policy that adaptively manages across multiple interconnected objectives (Knüppe & Pahl-Wostl, 2011; Megdal et al., 2015).

As with many areas around the world, the challenges summarized above (organizing and enhancing governance structures; addressing the diversity of water users' interests and needs; and using science-informed adaptive management) have been a barrier to groundwater governance throughout California. Below we provide an overview of California's historical approach to groundwater governance and how, through SGMA, it has sought to overcome them.

3 Groundwater Governance in California Prior to SGMA

As noted earlier, California is a large, diverse, and groundwater-dependent state (DWR, 2018a). Across the state there are 515 groundwater basins (Fig. 1), 127 of which are deemed high or medium priority due to the pressures upon them; with 21 of the 127 considered to be in a state of critical overdraft (DWR, 2016a, 2018a). Groundwater used in these basins is subject to a body of water law that may be the most complicated in the United States. Groundwater in California is governed through multiple overlapping arrangements, including water rights, state-level administrative and legislative laws, regional agencies, and local-level agencies and

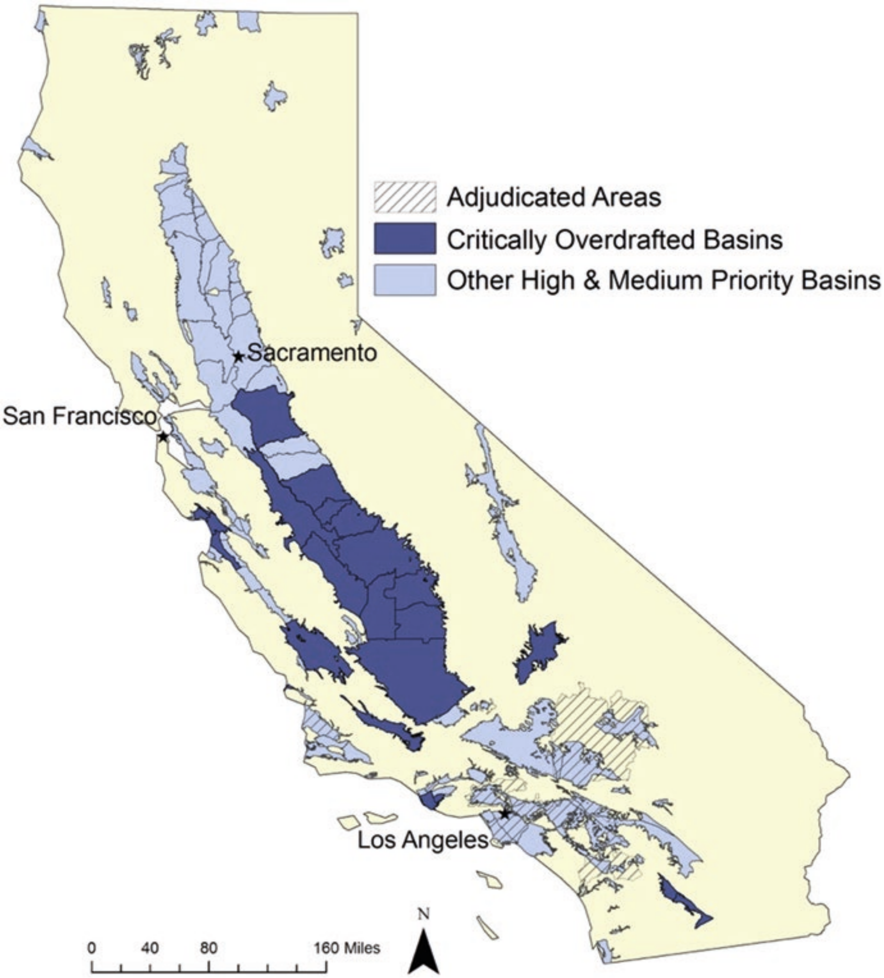

Fig. 1 High and medium priority groundwater basins in California, including those designated as critically over-drafted. Based on 2016 prioritization. [Data source: DWR, 2016a]

ordinances. In this section, we review the evolution of groundwater governance and management over the last 30 years as California has grappled with increasing demands on water resources, variable climatic conditions, and changing values regarding beneficial use of groundwater.

Rights to the use of underground water supplies in California are recognized and allocated by a multi-faceted (and sometimes overlapping) set of rules. These rules recognize overlying land ownership; prior withdrawal and use of groundwater: recovery of water that introduced directly or indirectly into an aquifer; and the acquisition of prescriptive rights through uninterrupted invasion of other users' rights (Bachman et al., 1997; Blomquist, 1992; Littleworth & Garner, 2019). Underground flows of surface water streams are distinguished in California law from "percolating groundwater" or groundwater per se and is treated as if it were surface water. Unlike surface water, there is no statewide permitting system in place for the withdrawal of percolated groundwater. Rights to groundwater use in California have been determined on a local basin-by-basin basis, primarily through adjudication, when they have been determined at all. Outside of 24 adjudicated basins, groundwater in California is treated as a common resource and all overlying landowners have unquantified and correlative rights to its use. Supplementing the allocation of water rights, are a number of groundwater management institutions, laws and regulations.

Consistent with the state's political tradition of supporting local governments and home rule (Krane, Rigos, & Hill, 2001), California has operated mainly to support local water management. State government has performed this function by acceding to most requests for the creation of local special-purpose districts or agencies, by providing incentives and assistance to local agencies, and by conveying surface water from the water rich, northern part of the state to the central and southern regions through the State Water Project. The California State Water Resources Control Board (SWRCB) and the California Department of Water Resources (DWR) are the two prominent state agencies concerned with the allocation and management of water supplies. The Water Resources Control Board administers the surface water right permit process, but also includes a system of Regional Water Quality Control Boards with authority to issue rulings, orders, and fines concerning land or water uses that may impair water quality. The California Department of Water Resources operates the State Water Project and conducts studies of water conditions and the hydrogeologic properties of water resources.

Beyond state-level government, local water management activities are performed by an immense array of governments, including hundreds of counties and municipalities, thousands of special districts, and dozens of joint-powers authorities. Most water districts in California were created under general-purpose legislative enabling acts, each of which creates a class of water districts with a different mix of authority and responsibilities. Enabling acts have been the basis for county water districts, irrigation districts, California water districts, municipal water districts, flood control and water conservation districts, water storage districts, and community service districts. California also features many special-act districts, created by their own legislation. Although some local water agencies—most notably water storage districts, water replenishment districts, and groundwater management agencies—are authorized to manage groundwater extractions or to develop and operate water replenishment programs, they represent a minority of California water organizations with clear authority to manage either groundwater pumping or groundwater storage. Most local agencies lack clear authority to manage either groundwater pumping or groundwater storage.

In 1992, in an effort to promote groundwater management within the state while retaining the tradition of local control, the California legislature enacted Assembly Bill (AB) 3030 (See California Water Code [CWC] § 10753). Under AB 3030, the authority to engage in a wide variety of groundwater management activities was conferred upon any type of local water district, as long as it undertook an extensive process of consultation and planning with all other water agencies and general-purpose governments overlying a basin (CWC §10753.7). AB 3030 did not, however, provide local authority to assign, allocate, or restrict groundwater rights (CWC §10753.9). Senate Bill 1938, signed in 2002, amended AB3030, incentivizing the groundwater management, by making state funding of groundwater projects contingent on development of groundwater management plans (DWR, 2019a).

Other state efforts to support local groundwater governance include the 1999 California Budget Act, directing DWR to develop model ordinances for groundwater management; the Local Groundwater Management Assistance Act, which provided assistance for local agencies to conduct scientific studies to improve management; the Groundwater Quality Monitoring Act, designed to improve coordination between monitoring networks, and the 2002 passage of the Integrated Regional Water Management (IRWM) Planning Act, which provided local agencies with incentives to cooperatively manage water. Following passage of the IRWM Planning Act, DWR developed guidance documents to support local development and adoption of management plans. (Grabert & Narasimhan, 2006). Lastly, in 2009 California took legislative action to establish the California Statewide Groundwater Elevation Monitoring (CASGEM) Program with the goal of improving state and local monitoring of groundwater elevations throughout the state (CWC §10920.(a,b)). By 2012, there were a total of 10,834 wells being monitored throughout the state (DWR, 2013). The CASGEM program has allowed DWR to classify basins based on their state of overdraft every 5 years (DWR, 2013).

Despite numerous state efforts to promote better groundwater management in California, groundwater levels in much of the state continued to decline. In the Central Valley between 2003–2010, 26 million acre feet of water were extracted, yielding various deleterious effects such as land subsidence, seawater intrusion, and diminished surface water flows (DWR, 2013; Leahy, 2015). By 2012, many state groundwater policy initiatives had been tried in California. There were some locally initiated successes but also many false starts and widespread continued reluctance. Groundwater data were getting better, but there were still considerable gaps, and the data that had been collected were often collected inconsistently and in different formats, leading to issues of incompatibility (Hanak, 2011; Nelson, 2012). State policies that tried to encourage groundwater planning and management had produced mostly disappointing results. Of the 119 groundwater management plans adopted under AB3030, only 82 were considered active by DWR and only 35 were in full compliance with California Water Code (DWR, 2013) Further, though local agencies who created plans under AB3030 were empowered to impose mandatory and fee-based policies to curtail groundwater extraction, few local government agencies elected to do so (Nelson, 2012). Where local management existed, it tended to be controlled entirely by pumpers' interests with little recognition or incorporation of other uses and values.

The pre-SGMA experience provided important lessons for the study of groundwater management generally and for California state policymakers in particular. On one hand, California's enabling environment allowed for considerable local initiative and supported local action where it occurred. There are locally managed basins (e.g. Orange County) within California that have been managed within a safe yield for long periods (Ostrom, 1990; Blomquist, 1992) and some are internationally renowned models of groundwater management. On the other hand, having a legal framework that addresses groundwater and allows local action is not enough to produce effective groundwater management everywhere. At best, having state groundwater laws and programs is a necessary condition. At worst, state groundwater laws and policies may inhibit the development of effective groundwater governance and management at the local level, and there are reasons to believe that California's complicated body of groundwater law has had that effect. The state's complex and changing system of water rights distributed veto positions and claims of superior rights to enough different interests that many perceived themselves and their water use to be immune from change. Even state-provided incentives (including the availability of funding) were unable to move enough groundwater users away from the deteriorating status quo. With the inadequacies of California's approach to groundwater governance exposed, the stage was set for crafting a new law to address the multiple negative impacts caused by over-extraction.

4 The Sustainable Groundwater Management Act

Governor Jerry Brown signed the Sustainable Groundwater Management Act (SGMA) into law in 2014. The drafting and passing of SGMA—which is a three bill package AB 1739 (Dickinson), SB 1168 (Pavley), and SB 1319 (Pavley)—was a highly contested process, with many environmental organizations and water policy institutes (e.g. Public Policy Institute California Water Policy Center) in favor and many local municipalities, particularly counties in the Central Valley and food production lobbyists (e.g. California Aquaculture Association and California Federal Farm Bureau) against (DiMento, 2017; Leahy, 2015).

SGMA was passed with the goal that local governments achieve sustainable groundwater management across all groundwater basins designated by DWR as medium to high priority (CWC §10720.7). To do so, SGMA requires the formation of new governing bodies - Groundwater Sustainability Agencies (GSAs) and delegates to them responsibility and authority to plan for and manage groundwater to achieve sustainability. Existing local agencies interested in becoming GSAs had until June 2017 to formally notify DWR with their intent to become a GSA in their basin (CWC §10723.8). Existing local agencies were given the option to independently become a GSA or partner with other existing agencies to jointly form a GSA (CWC §10723.6). To make sure the entire expanse of each groundwater basin was covered by a GSA, SGMA designated counties as the default GSAs, though counties could opt out of being a GSA (CWC §10724.a).

SGMA requires groundwater sustainability be achieved at the basin scale, and defines sustainability as the avoidance of six undesirable results: chronic lowering of groundwater levels, reduction of groundwater storage, seawater intrusion, degraded water quality, land subsidence, and depletions of interconnected surface water (California Code of Regulations [CCR] §354.26). To help them meet this requirement, GSAs are tasked with developing and implementing Groundwater Sustainability Plans (GSPs). In developing GSPs, GSAs must ensure their planning is based on the best available science and must adopt an adaptive approach, evaluating the status of the basin and updating plans every five years. Groundwater Sustainability Agencies must also plan for and implement specific management actions and projects that are designed to avoid the negative impacts referred to by SGMA as undesirable results (CCR §354.44). Throughout the planning and implementation process, GSAs need to adopt a transparent approach that includes the multiple perspectives of diverse stakeholders, many of whom have conflicting values and perspectives (CWC 10727.8).

While SGMA mandates that sustainability should be achieved at the basin scale, DWR regulations do not limit the number of GSPs in a basin (CCR § 355.4.b). Figure 2 illustrates the various combinations of GSPs that may occur. The simplest of these is the case where a single GSP covers the entire basin and is developed and implemented by a single GSA. Slightly more complex is a case where a single plan covers the entire basin, but is developed and implemented by multiple GSAs. Lastly, there could also be multiple GSPs within a basin that are developed and implemented by multiple GSAs. In cases where there are multiple GSPs covering the basin, GSAs are required to make formal coordination agreements with all GSAs in the basin that are developing a plan, showing that GSAs are working in a coordinated effort to achieve sustainability on the basin scale (CWC §10727).

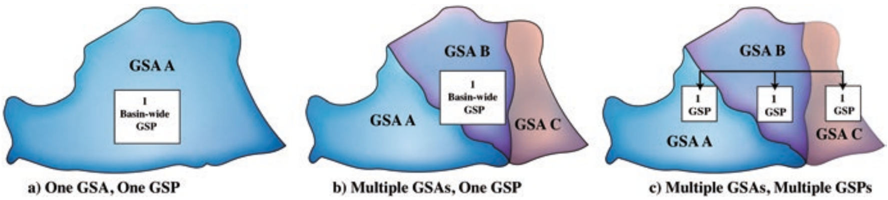

Fig. 2 Illustration of the multiple approaches GSAs may take when submitting groundwater sustainability plans (GSPs). [Picture adapted from (DWR 2016b)]

Groundwater Sustainability Agencies must work on a short deadline in order to comply with SGMA. Groundwater Sustainability Plans for basins that are currently experiencing overdraft conditions must be submitted by January 2020. The plans for all other medium and high priority basins must be submitted by January 2022. After submittal, DWR will evaluate submitted plans to determine if a plan is considered approved. If a plan is considered inadequate, the SWRCB acts as a backstop by placing the basin on probation thus requiring GSAs within that basin to file extraction reports with the state. In cases where a plan is out of compliance, the state, acting through the State Water Resources Control Board is given authority to develop their own groundwater plans, take over management of groundwater resources in the basin, and charge a management fee (CWC §10735.6–8).

5 SGMA's Approach to Groundwater Governance Challenges

SGMA did not attempt to supplant local groundwater management where it had developed. Existing local arrangements – particularly the allocation and limitation of groundwater withdrawals in the adjudicated basins and the groundwater taxing and recharge programs of various special districts – were largely grandfathered by SGMA and left in place with the addition of some reporting requirements. The bridge from the pre-SGMA environment in California to the current situation was built instead on attempts to address the aforementioned groundwater governance challenges.

5.1 Organizing and Enhancing Governance Structures

SGMA adopts a hybrid institutional structure that merges state-level oversight with local-level governance, and in doing so, addresses many shortcomings and tensions associated with developing polycentric systems of governance. At the core of SGMA is the principle that local agencies are best able to govern and manage groundwater within their jurisdictions. The law grants the local level entities that form GSAs substantial responsibility and authority (CWC §10725) and provides local decision-makers a maximum amount of flexibility to adapt institutional structures, jurisdictional boundaries and groundwater management to local contexts. Yet SGMA also requires sustainability be achieved at the basin scale, and, where multiple GSAs are producing multiple GSPs within a basin, those GSAs must coordinate the data information and assumptions and demonstrate how their varying analyses and efforts are compatible with sustainability on the basin scale (CCR §357.4.a). Further, SGMA also provides a backstop by granting the state the power to intervene in basins that are non-compliant with the law's regulatory requirements (CWC §10735.2).

For such a hybrid approach to organizing and enhancing governance structures to be successful, GSAs will need to overcome significant challenges and constraints. Local-level agencies forming GSAs face the challenge of forming resilient institutional and decision-making governance structures that have the financial and technical capacity to develop their management plans by the statutory deadline. While the state has provided assistance to GSAs, in the form of technical support, best management practices and opportunities for financial assistance for coordination, GSA responsibilities and the resources and capacities needed are still quite large (Kiparsky et al., 2016). Further, SGMA's requirement groundwater sustainability be achieved at the basin scale compels existing local agencies to plan beyond their individual, jurisdictional boundaries. Where multiple GSAs exist in a basin, this means that some elements of compliance with the law are beyond their control. Coordination of data, methodologies, metrics, and goals requires communication and a will across multiple parties. Historical relationships, current differences and differential GSA capacities and concerns will influence how coordination plays out. Groundwater Sustainability Agencies may also face challenges to their newly vested power and authority. Interest groups may challenge a GSA's authority to manage groundwater, resulting in potentially lengthy and costly court battles. These challenges may come from external entities or from a GSAs own constituents, either with the concern that the GSA is not doing enough to achieve sustainability or with the concern that the GSA has adopted rules and polices that negatively affect local, agricultural economies.

GSA compliance will also be constrained by factors external to SGMA. GSAs must plan for and take actions to achieve groundwater sustainability in the context of the multitude of pre-SGMA laws and regulations that exist across the state. SGMA does not change or affect surface water rights and laws or prior groundwater adjudications. Further, the local-level entities forming GSAs are all subject to the various public administration, tax, and other laws governing local-level governmental agencies throughout the state. The outcomes of SGMA are thus contingent on the ability of GSAs to navigate this complex regulatory environment as they seek to govern groundwater for sustainability.

Lastly, the outcomes of SGMA will very much depend on how GSAs interpret the threat of state intervention. If GSAs are unconcerned about the threat of state-level intervention in the basin, they may lack motivation to implement policies that are stringent enough to achieve groundwater sustainability. For some GSAs, state intervention may not be viewed negatively and may even be welcomed. This may especially be true in cases where the relationship between the GSA and their constituents prevents the GSA from undertaking policies it sees as necessary. If the threat of state intervention is not taken seriously, it remains to be seen the impacts on state resources and capacities.

5.2 Incorporating Diverse Interests and Values

SGMA explicitly requires incorporation of the diverse interests and values of groundwater by mandating GSAs provide opportunities for stakeholder engagement. Throughout the GSA formation process and plan development, GSAs were tasked with gaining a detailed understanding of who their stakeholders were and keeping them informed through notification. Local agencies forming GSAs had to identify, notify, and consult all of the beneficial uses and users in the basin (CWC §10723.1–4) prior to GSA formation. Further, prior to preparing a GSP, GSAs had to provide written notice town, city or counties located within a geographic area covered by a plan (CWC §10727.8) and to any report to DWR on how interested parties could engage with the GSA on development of the GSP (CCR §353.6.a).

Moreover, the extent to which GSAs provide avenues for stakeholder engagement and address the interests and values of groundwater uses is one of the metrics the DWR will use to evaluate GSPs (CCR §355.4.b.4,10). GSAs must, therefore, include a description of the beneficial uses and users of the groundwater basin (CCR §354.10.a), including groundwater dependent ecosystems (CCR §354.16.g) in GSPs. GSAs must also design monitoring networks to track impacts of groundwater use on beneficial uses and users in the basin and adjoining basins (CCR §354.34.f.3). When submitting the GSPs, GSAs must demonstrably show how they engaged these interests by providing a list of public meetings the agency held and a description of the agency's decision-making process, which includes an account of how public engagement was incorporated into the plan's development (CCR §354.10.b-d). Beyond incorporating stakeholder feedback, GSAs must also outline the process by which interested parties are informed of potential management actions (CCR §354.44.b.1.B).

SGMA's mandate that GSAs consider the full range of interests and values of groundwater users and provide substantive and meaningful avenues for stakeholder engagement push GSAs beyond familiar notification and public comment processes and toward the aim of greater inclusivity consistent with calls for resilient governance (Ebdon, 2002; Nabatchi & Amsler, 2014). Yet the extent to which this requirement serves to facilitate governance, including producing more balanced or innovative policies, garnering support, reducing conflict, increasing compliance, etc., will depend on how GSAs implement these requirements. As the regulations do not provide specific requirements regarding the mechanisms to be used for engagement, nor the extent to which engagement must occur, GSA interpretations of the mandate and their capacities and will to engage, will have a strong impact on engagement outcomes.

Integration of diverse interests into governance and development of meaningful mechanism for engagement and participation are challenging processes (Carr, 2015). Success will likely vary across GSAs. Identifying and engaging with the full scope of beneficial users and affected parties is complex. While some GSAs have incorporated representatives from stakeholder groups into their boards or have created advisory roles for those stakeholders (Conrad et al., 2018; Milman, Galindo, Blomquist, & Conrad, 2018), other GSAs are relying solely on less formalized engagement and participation mechanisms. Reaching out to stakeholders is time consuming, costly, and requires skills and capacities that GSAs may not have. For example, while counties have institutionalized requirements and processes for such engagement, other entities, such as small water districts may have less experience and expertise. Further, GSAs need to consider stakeholders who fall outside their own social, cultural, and economic understandings. Such engagement may require translators in order for communication to occur with stakeholders who do not speak English. Additionally, GSAs, particularly in the critically over-drafted basins, have a short time frame in which to develop GSPs. Transparent and inclusive processes can entail substantial transaction costs, and the GSP development timeline is quite short. Lastly, meaningful engagement requires stakeholders have a fairly deep knowledge of the requirements and specific meanings of technical terms. As described below, groundwater is highly technical and SGMA requires GSAs adopt science-informed policy making. Many of those affected by SGMA lack knowledge of groundwater systems and familiarity with the regulations. Thus, the success of GSAs in engaging with stakeholders will also be contingent on GSAs ability to educate and communicate, as well as stakeholder willingness and abilities to learn.

5.3 Using Science-Informed Adaptive Management

SGMA answers the call for governance that supports knowledge-driven adaptive management (Burton & Molden, 2005) while pushing for policy and management actions based on current understanding of the system, even in cases where that knowledge is minimal. As discussed earlier, SGMA regulations require that GSAs identify where they lack understanding and then outline their plan for expanding monitoring networks to fill knowledge gaps. In their five-year updates, GSAs must assess their monitoring networks and data management systems. They must also examine how their current policies and management actions are meeting their plan's interim milestone targets to avoid undesirable results. GSAs that are not meeting their targets must articulate in their GSPs what changes they will make to achieve sustainability by 2040. If updated plans are not re-approved by DWR, the intervention process outlined above takes effect, which may result in SWRCB taking over management in a basin (CCR § 356.2; CCR §356.4).

GSAs face barriers to gaining the level of understanding needed to develop and implement their plans. While the state of California has made effort to gain knowledge of groundwater systems and has developed several modeling tools to inform GSA policy and management actions, there are still large gaps in data and understandings that GSAs will need to fill (Moran, Cravens, Martinez, & Szeptycki, 2016; Moran & Wendell, 2015). Yet filling those gaps is fraught with technical, logistical, and financial challenges. For many GSAs, acquiring new data and turning that data into information requires technical expertise outside their capabilities. Thus, they will need to hire technical consultants, adding to the financial costs of plan development. GSAs may also face legal challenges in establishing well monitoring networks, requiring extensive negotiations with private landowners and state and federal agencies. Similarly, data a GSA needs for understanding a portion of the basin outside their jurisdictional boundaries may be proprietary. Lastly, even in cases where GSAs have a sufficient amount of data, that data may be of poor quality or incompatible due to a lack of standardized data collection methods and protocols.

The requirement that GSAs implement adaptive management also poses significant challenges. Design and implementation of the projects and management actions that will be used to achieve groundwater sustainability requires substantial time, analysis, and at times resources. Projects may require securing grant funding, acquiring land, developing infrastructure, navigating existing legal requirements and approvals, and drafting complex sets of rules. Adapting projects and management actions in a short timeframe, or even at all, may be infeasible. The time lag between when GSAs submit their GSPs for evaluation and periodic review and when DWR is able to complete evaluation of the plan is another challenge for adaptation. A GSA is expected to begin implementation of their GSP once it is adopted; however, DWR has 2 years to evaluate the first iteration of GSPs. Consequently, GSAs must make decisions and begin implementation without the certainty their plan will be approved by DWR.

Lastly, implicit in SGMA's requirement that GSAs use best available science for adaptive management is the need for high levels of collaborative knowledge production and decision-making between large numbers of actors with various perspectives, levels of expertise, and motivations. In basins where multiple GSAs are developing GSPs, SGMA requires GSAs develop formal agreements and processes for data and information sharing (CCR §357.4.a), yet GSAs still have a high degree of agency in determining what those agreements and processes contain. How well these institutional processes facilitate basin-scale knowledge production may determine successful implementation of policies and management actions, particularly if high levels of collaboration decrease the prohibitive costs associated with acquiring groundwater data and information—often thought a barrier to science-based management (van der Gun, 2017).

6 SGMA as a Model for Resilient Groundwater Governance?

California's adoption and implementation of SGMA, if successful, may serve as a model for resilient governance of groundwater in multi-level governance contexts elsewhere in the United States and around the world. However, California's success (or failure) in achieving groundwater sustainability may be as much attributable to the design of this new governance system as to the defining political, economic, and social contexts of California. As such, scholars and practitioners must consider which aspects of SGMA are likely generalizable and which may be peculiar to

California. Here, we discuss the potential for SGMA to inform global groundwater governance and draw attention to unanswered questions about the transferability of SGMA.

First, it is worth noting while not all groundwater users or managers are in favor of SGMA, both governmental and non-governmental entities are dedicated to its success. The State of California has invested vast financial and technical resources to ensure SGMA is successful. It has awarded over 85 million dollars in grants and loans to support GSA formation, GSP development, and GSP implementation, financed through bond measures and the state budget (DWR, 2019b). Further, through the Department of Water Resources, the state has developed best management practices, model ordinances, and other examples for GSAs to draw upon. The state has also hired additional staff to ensure it can provide advice and the high level of oversight mandated by the law. In addition, countless academics, universities, non-governmental organizations, policy think tanks, and professional associations have been offering a range of services including undertaking analyses; providing advice; organizing and facilitating workshops and trainings; creating websites and otherwise disseminating information. The high-level of engagement by both the state and civil-society has been an important element of the early stage implementation of SGMA and may or may not be replicable by other states or governments.

Another unique aspect of SGMA is that it is not starting *tabula rasa*. SGMA builds upon California's existing institutional structures and water management policies that for decades have served to engage policy makers and water managers in water management and in collaborative planning. The local-level agencies eligible to form GSAs have prior experience managing surface and groundwater, and with engaging in planning processes. In addition to participating in development of California's state-wide water plan, many of these agencies (along with county and city governments) have developed integrated water resources plans, urban water management plans, and groundwater management plans under AB3030. Lastly, while large data gaps do indeed exist, SGMA is not being implemented in a data vacuum. Substantial data and information on water resources geology, climate, and more are available through repositories, such as the Water Data Library, California Irrigation Management System, and Groundwater Information Center. Further, the state has developed myriad localized datasets and models, such as the California Central Valley Groundwater-Surface Water Simulation Model (C2VSIM), and local-level agencies have information based on their management of water over the past decades (Department of Water Resources, 2018b). This history of collaboration, management models, and information may be imperfect and incomplete, but provides a starting point from which SGMA builds.

Yet this robust history also provides a potential constraint to implementation of SGMA. Governance, and institutional formation, is frequently the result of bricolage – in which mechanisms for governance are borrowed from or reconstructed from existing sources (Cleaver, 2017; Merry & Cook, 2012). The GSAs formed under SGMA were created by existing local-level agencies, which voluntarily took on new responsibilities themselves or in partnerships. The extent to which these agencies adopt novel institutional approaches or choose instead to govern as an extension of past practices is still unfolding. It is possible that bricolage may lead to inefficiencies or barriers to information sharing and decision-making (Milman & Scott, 2010). Conversely, local level agencies may develop truly novel institutional structures and arrangements, driven by the need to comply with the short statutory deadlines In particular, the processes and mechanisms GSAs use to coordinate their knowledge production with other agencies, engage in meaningful dialogue with stakeholders and interest groups, and adopt adaptive management policies may be different from previous approaches or may be continuations of the same. What choices they make will likely depend on history, resources, and imagination, informed by legal and technical considerations.

Another factor influencing both implementation of SGMA and its applicability as a transferrable model for groundwater governance is the role of state agencies in California who are charged with oversight and enforcement. While the state has invested large amounts of time and resources to ensure SGMA is successful, it is unknown how state regulating and enforcing agencies (e.g. DWR and SWRCB) will adapt to their respective roles as evaluators and enforcers of the mandatory requirements of the law. These agencies have historically not had a strong enforcement role within the state, and have limits to their human resource, financial, and legal capacities. The extent to which local agencies perceive the threat of state intervention as credible may influence their depth of compliance with SGMA. Further, even if GSAs take seriously the threat of state intervention, and try to comply fully, GSAs will likely interpret the requirements different from each other and the state. Thus, the state must adapt its dual role of continuing to support local agencies by providing clear guidance while maintaining a perceived power differential. This distinctive interplay between the state and local agencies is integral to the success of SGMA and should be considered if applied to other political and regulatory contexts.

SGMA's novel approach to achieving groundwater sustainability may be one of the most intentional efforts currently underway to promote resilient groundwater governance. Therefore, implementation of SGMA is a natural experiment from which scholars and practitioners can learn about groundwater governance processes. Close examination of SGMA as it unfolds, including its successes and its shortcomings, can help provide insights on how to organize and enhance governance structures, incorporate the diverse interests and values of groundwater users, and adopt science-informed adaptive management across multiple objectives. Specific attention should be given to the multitude of contextual factors influencing implementation, so as to illuminate which aspects of SGMA are transferrable, and where adaptations need to be made to ensure applicability to other locations. Whether or not SGMA is immediately successful in curtailing over-extraction of groundwater in California, implementation of this law will alter our understanding of what resilient groundwater governance looks like and will likely lead to redefinitions of the metrics by which we measure success or failure. If, however, SGMA achieves its aspirational goals, the lessons learned offer hope of a solution to the common challenges of groundwater governance.

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Water Policy Reform for Sustainable Development in the Murray-Darling Basin, Australia: Insights from Resilience Thinking

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Abstract This chapter explores how insights from Resilience Thinking (RT) can better inform efforts to reform water policies in directions required for sustainable development. The focus is on the Murray-Darling Basin (MDB) in Australia, and particularly on reforms seeking to achieve environmentally sustainable water use. We find that the reform process remains dominated by a conventional, command-and-control, management approach that asserts predictability yet repeatedly delivers uncertainty in its place. In contrast, the approach favoured in the RT tradition for water policy reform in the MDB would involve adaptive co-management. This approach would avoid those surprises arising from the conventional approach's misguided confidence in the predictability and controllability of the reform process, while being fit-for-purpose in dealing with the irreducible uncertainty of outcomes from intervening in the Basin's complex social-ecological dynamics. An RT perspective highlights that shifting to adaptive co-management of the reform process would require transformation of existing governance arrangements that evolved in support of the conventional management approach. The MDB experience suggests that it is possible for such transformation to emerge through the cross-level dynamics associated with the resilience approach's concept of panarchy. Local-level entrepreneurship by NGOs (as bridging organisations) in environmental water management has in this case established a foundation from which transformative governance of the Basin's sustainability-driven water reform agenda continues to evolve. We conclude that RT can make important contributions to understanding how longstanding challenges in reforming water policy for sustainable development might effectively be overcome.

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1 Introduction

Existing and looming water crises have prompted efforts around the world to reform policies in this sector. Limited success in these efforts means “the need to reform water policies is as urgent as ever” (OECD, 2012 p. 1). A key driver of water reform efforts in many countries is threats to sustainable development posed by the degradation of freshwater ecosystems arising from over-allocation of water to irrigation and other consumptive uses (Garrick, 2015). The slow progress achieved to date in reforming water policies for sustainable development has spurred various critiques of the methodology under which the dynamics of water management have conventionally been understood. The focus of this chapter is on the alternative methodology presented by Resilience Thinking (RT) (Walker & Salt, 2006).

Application of RT principles and approaches to water management practice has been impeded by existing governance structures (Benson & Garmestani, 2011; Stayner & Parsons, 2018). The chapter therefore explores how water governance might be transformed to enable the resilience approach to be embedded in water management and policy processes, and how this may facilitate effective reform of water policies onto the trajectories required for sustainable development. Given that “restructuring current institutions and governance systems for resilience is no small task” (Folke, 2016 p. 12), insights from RT into obstacles and opportunities in achieving such governance reform are considered.

These issues are explored through a case study of the Murray-Darling Basin (MDB) in Australia. Despite the efforts at sustainability-driven water policy reform that have been underway in this setting since the 1990s, and international recognition of these efforts as world-leading (Productivity Commission, 2017), implementation of the reforms agreed to by governments remains well short of what is required to return water extractions to environmentally sustainable levels (Grafton, 2019).

The remainder of this chapter is organised as follows. Aspects of RT relevant to the chapter’s focus are reviewed in Sect. 2. The context of the MDB case is described in Sect. 3. The history of efforts to implement sustainability-driven water policy reforms in the MDB is interpreted in Sect. 4 through an RT lens. In Sect. 5 the focus shifts to the governance challenges encountered in implementing these reforms and to an RT interpretation of responses to these challenges. In Sect. 6 conclusions are presented.

2 Resilience Thinking

2.1 The Conventional Management Paradigm

The conventional 'command and control' paradigm of environmental management to which RT presents an alternative assumes that the dynamics of all systems to be managed are mechanistic, with unchanging parts and relationships between parts (Marshall, 2010). It follows that behaviour of a system is predictable from the behaviour of its parts, and that any system will remain in equilibrium, or stable, until disturbed by changed external conditions. Any such disturbance is seen as leading to a new equilibrium for the system, which is predictable due to its unchanging cause-and-effect relationships. The prior equilibrium can be restored by reversing the disturbance (Walker & Salt, 2006).

The assumption of constant cause-and-effect relationships means also that relationships between particular elements of a system can be modelled in isolation from other system elements, at least when (as is common under the conventional paradigm) an assumption of 'all else remains constant' or 'current trends continue' is applied to the other elements. 'Best management practice' under the conventional paradigm thus came to involve optimising specified elements of a focal system by controlling a few of its other elements. Such control is understood as seeking to shift the system to an optimal equilibrium state which will persist until further external disturbance eventuates (Walker & Salt, 2006).

2.2 Social-Ecological Systems and Complexity

RT scholars argue that the assumption of social and environmental systems behaving mechanistically is flawed and became even less fit-for-purpose as a basis for environmental management as humanity's increasing impact on the life-supporting biosphere moved it into the Anthropocene era (Folke, 2016). Arguing further that it is increasingly inaccurate in this era to characterise human and environmental systems as independent of each other rather than coevolving, they propose that the appropriate focus of management should be on social-ecological systems (SES) which are "intertwined systems of people and nature embedded in the biosphere" (Folke, 2016 p. 2) that behave as complex adaptive systems.

A complex adaptive system consists of multiple autonomous elements in ongoing interaction with one another and with the system itself. It is called complex because its patterns of behaviour are emergent; i.e., they cannot be understood by focusing only on the behaviour of its elements. In contrast to a mechanistic system, the parts of a complex adaptive system and the relationships between them are continually adapting to one another and the state of the system as it evolves due to these adaptations and external disturbances. Predictability of the consequences for the state of a complex adaptive system of any external disturbance, including efforts to control system behaviour, is therefore low, and system response exhibits high levels of surprise (i.e., unforeseen events) (Berkes, 2017; Ison, Alexandra, & Wallis, 2018).

Aside from RT, the concept of adaptation pathways has emerged as a metaphor to help understand processes of adaptation and transformation in complex adaptive systems (Wise et al., 2014). This metaphor portrays "the state of a system [as] channelled within an evolving stability domain,[1] the resilience of which changes though time" (Abel et al., 2016 p. 4). Although resilience is not necessarily invoked in applications of the adaptation pathways concept (e.g., Gelcich et al., 2010), Abel et al. (2016) has argued that the concept is consistent with RT.

The approach to management favoured in the RT tradition is one of adaptive co-management, in which "institutional arrangements and ecological knowledge are tested and revised in a dynamic, ongoing, self-organized process of learning by doing" (Folke, Hahn, & Olsson, 2005 p. 448). This approach combines active adaptive management with co-management. The former involves an orientation towards "'learning by doing' through iterations of assessing opportunities, designing policies as experiments, implementing actions, and adjusting course in light of monitoring and evaluation" (Plummer & Baird, this volume p. 11). The latter involves collaboration across organisational levels, which in turn requires problem-solving and decision-making powers to be shared across the levels. Adaptive co-management is thus a social learning process that requires collaboration among diverse stakeholders situated at multiple organisational levels (Folke et al., 2005). An analogous process of socio-institutional adaptive learning was identified by Pahl-Wostl (2007) as necessary for water resources management in a world of dynamic climate and social change.

2.3 Resilience

The state of a particular SES can vary within the boundaries of what RT scholars refer to as its stability domain without changing its structure and function. These boundaries are referred to as thresholds. While the state of the SES remains in a particular basin, it tends to gravitate towards an equilibrium state. This equilibrium shifts over time as the shape of the basin changes under the influence of external conditions, and the state of the SES tends to follow the shifting equilibrium, thus tracing an emergent development path (Walker & Salt, 2006). Stable patterns of vested interests and cognition emerge from the path traced, and these constrain opportunities to change the path's trajectory through policy or governance reform. Institutional analysts associated with the RT tradition refer to such self-reinforcing sequences as institutional path dependence (Marshall, 2013).

RT scholars propose that multiple stability domains exist at any time for a particular SES. The feedbacks driving the dynamics of an SES change if its state

[1] This concept is discussed in Sect. 2.3.

crosses the threshold bounding its current stability domain and enters one of the alternative basins. The new stability domain will have its own equilibrium state which will shift as external conditions influence the shape of that stability domain. The system will then have a new structure and function, and a new development path (Walker & Salt, 2006). The transition of an SES's state from one stability domain to another can be non-linear. Seemingly minor disturbances can 'flip' the system to an alternative basin, with major consequences for system structure, function and feedbacks. Such transitions are often surprising given that the alternative basin into which the system ultimately flips, and the timing of the flip, are rarely predictable with confidence (Berkes, 2002).

Resilience is understood in the RT tradition as the capacity of an SES to absorb disturbances and reorganise without its state crossing a threshold to an alternative stability domain. Progressively smaller disturbances are required to shift an SES into a different basin as its resilience diminishes. Assessment of whether resilience of a particular SES is desirable is value-laden. Adaptation refers in the RT tradition to human actions that sustain development on a current path. Those whose values indicate that the SES should move onto another development path may work towards preparing for its transformation (Folke, 2016).

2.4 Transformation

Transformation of an SES is understood in the RT tradition to become increasingly likely as its development path brings it towards the end of the fore loop of what is known as the adaptive cycle. This cycle is identified as a means of characterising the progression of an SES through different phases of organisation and function. Its fore loop comprises the phases of rapid growth and conservation. The back loop is normally much shorter and consists of the phases of release and reorganisation (Walker & Salt, 2006).

The adaptive cycle was proposed as a metaphor for understanding long-term dynamics of change in SESs and complex adaptive systems more generally, and it does not imply fixed, regular cycling. Walker, Holling, Carpenter, and Kinzig (2004) recognised that actual systems can move back from conservation to rapid growth, or from rapid growth directly to release, or back from reorganisation to release. Sundstrom and Allen (2019 p. 1) proposed more recently on the basis of their synthesis of research from a diversity of disciplines, including on evolution of social systems, that "adaptive cycle dynamics are ubiquitous in complex adaptive systems … [A]daptive cycles are real dynamics of real systems and not just handy conceptual metaphors …" (p. 1). Abel et al. (2016) have argued that the adaptive cycle is consistent with the adaptation pathways concept: "an adaptation pathway is … likely to proceed through alternating incremental and transformational changes" (p. 5).

In the conservation phase the elements of an SES become more strongly interconnected, the system becomes increasingly less flexible, and its resilience diminishes. The magnitude of disturbance needed to initiate the back loop, during which the SES may transform and thus commence a new development path, tends to become smaller the longer the conservation phase persists. The development path subsequently ‘chosen’ may be determined by small random events, as well as by the exercise of power. Those benefiting from the status quo and in positions of power often seek to ward off transformation given its potential to disrupt their agendas. Power can be employed to divert public resources to bolster the resilience of the existing SES. Nevertheless, RT scholars contend that an SES cannot be held indefinitely in the end stages of a conservation phase (Walker & Salt, 2006).

Rather than wait for transformation to eventuate, with all the uncertainty this involves, deliberate or intentional action can be taken to catalyse transformation in directions believed to be beneficial. RT scholars emphasise the importance of such efforts for transitioning onto a path of sustainable development, with Folke (2016) arguing that sustaining favourable biosphere conditions for humanity requires “transformations toward new ways of development, not just incremental tweaking of business as usual on current development pathways” (p. 8).

The RT approach to deliberate transformation focuses primarily on building transformability, which “is about … having the ability to cross thresholds and move social-ecological systems into … new, emergent, and often unknown development trajectories” (Folke, 2016 p. 5; see also Olsson, Galaz, & Boonstra, 2014). This ability includes preparing for and creating windows of opportunity, developing capacities to exploit these opportunities, enabling small-scale transformative experiments, and promoting learning and innovation across levels. The focus is on the relatively few slow-changing variables within an SES that determine the dynamics of the faster-moving variables of direct interest to managers. Crucial among these slow variables are mental models, social norms and values that influence social and political support for new approaches (Walker & Salt, 2006).

2.5 Transformative Governance

RT scholarship recognises that scope for deliberate transformation towards adaptive co-management is constrained by power relations embedded in existing governance arrangements established for the conventional approach to environmental management; i.e., by institutional path dependence (Plummer & Baird, this volume). The assumptions of system predictability and controllability underpinning this approach encourage confidence that management problems can be solved from afar by centralised authorities who are capable of controlling the actions to be implemented at lower levels (Marshall, 2010). In contrast, deliberate transformation requires the flexibility that adaptive co-management offers managers for self-organised ‘experimentation’ with, and learning from, novel development trajectories (Folke et al., 2005). More generally it requires transformative governance; i.e., governance with capacities to “actively shift a SES to an alternative and inherently more desirable regime by altering the structures and processes that define the system" (Chaffin et al., 2017 p. 400).

Transformative governance is polycentric (Chaffin et al., 2017). Polycentric governance comprises multiple units of governance at multiple levels of organisation, with substantive autonomy from one another: "no one is in charge" (Abel et al., 2016 p. 2). These units function as a system "to the extent that they take each other into account in competitive relationships, enter into various contractual and cooperative undertakings or have recourse to central mechanisms to resolve conflicts" (Ostrom, Tiebout, & Warren, 1961 p. 831). While RT scholars have tended to focus on the potential for polycentric governance systems to enhance management of complex adaptive systems, the institutional design challenges in realising this potential are formidable (Stephan, Marshall, & McGinnis, 2019).

A system of polycentric governance is itself a complex adaptive system, its emergent behaviour and performance the outcome of its constituent governance units adapting to one another and the evolving behaviour of the system (Ostrom, 1999). Like any CAS, a polycentric governance system exists at any time in one of multiple possible basins of attraction. The contribution of a polycentric governance system to transformability of an SES depends on which of the possible basins the governance system actually inhabits. Ostrom (1999) argued that the challenge of steering polycentric governance systems onto paths conducive to sustained human wellbeing is too complex to be solved optimally; rather it must be pursued by 'tinkering' with combinations of institutions to find ones that work together more effectively in present conditions. It follows that polycentric governance systems with greater capacities for such institutional 'experimentation' are more likely to navigate successfully onto paths offering transformability when this is required.

The capacity within a polycentric governance system for such experimentation, and for institutional adaptation or transformation informed by the knowledge gained, will increase to the extent that governance units across the system have the autonomy they require to engage in such a process (Ostrom, 1999). A key to achieving and maintaining this autonomy of governance units is the principle of subsidiarity. This principle requires that responsibility for each governance function, together with corresponding decision-making rights, be assigned to the lowest level at which it can be exercised competently. Subsidiarity thus endows all governance units, progressively upwards from informal local groups, with as much decision-making autonomy as they can competently exercise (Marshall & Lobry de Bruyn, forthcoming).

In accordance with self-determination theory (Ostrom, 2005) and associated empirical research in the environmental management context (Marshall, Hine, & East, 2017), greater autonomy of governance units can in turn be expected to strengthen their motivations to cooperate voluntarily with one another in effecting the institutional collective action required for polycentric governance to perform successfully as a system (Marshall & Malik, 2019). While leadership at all levels of an SES has been identified in the RT tradition as important for its transformability (Folke, 2016), leadership effectiveness depends on how voluntarily it is followed.

Substantive autonomy of the units of a polycentric governance system also gives the system what RT scholars describe as a modular structure (Walker & Salt, 2006): while the elements of each governance unit (e.g., directors, staff and volunteers) are strongly interlinked, the units themselves are connected only loosely to each other. This structure facilitates transformability of a polycentric governance system by making the system's 'building blocks' smaller. The smaller these building blocks, and the more autonomous they are, the lower will be the transaction costs of reconfiguring the system (Marshall, 2010).

Transitions to transformative governance nevertheless face obstacles from "the inertia of embedded power relations that govern most SESs towards an unsustainable maintenance of the status quo" and the mental models and value systems that have coevolved with those patterns of power (Chaffin et al., 2017 p. 410); i.e., from institutional path dependence (Noble, Harris, & Marshall, 2017). Resistance by governments to such transitions stems not only from self-interested considerations (e.g., electoral success) but also from the greater tolerance of risk that would be required from them (Chaffin et al., 2017).

Chaffin et al. (2017) argued that the RT concept of panarchy is the key to understanding how such obstacles can be overcome. This concept refers to how the state of an SES at one level influences its states at other levels (Walker & Salt, 2006). Steps towards transformative governance at one level of SES governance can thus be triggered by disruptions at a higher or lower level. As with attempts at deliberate transformation generally, the RT approach to transforming governance is to prepare by building the capacities favouring its emergence when permitted by windows of opportunity.

Smaller initiatives at lower levels may be more effective in the early stages of navigating to transformative governance, and "larger-scale transformation may occur only as personal or individual transformations are scaled up to forge the collective capacity to drive change" (Chaffin et al., 2017 p. 403). Governance experiments at lower levels, beyond the scrutiny of powerful actors seeking to block transformation, can enable a shadow network of actors to erode the dominant governance paradigm by demonstrating the advantages of alternative approaches. Bridging organisations including NGOs can bring in resources and knowledge to support these lower-level transformative initiatives and disseminate their learnings more widely. Such organisations can also lower the costs of collaboration between these initiatives and like-minded parties. Governments can facilitate self-organisation at lower levels through enabling legislation and recognition of bridging organisations (Folke et al., 2005). More centralised and formal approaches will typically be needed later in a transformation process to legitimise the emergent new governance regime and strengthen enforceability of its institutions (Chaffin et al., 2017).

Olsson et al. (2006) used a metaphor of 'shooting the rapids' to highlight the possibility that attempts to beneficially transform governance may fail due to turbulence encountered along the way, including opposition from powerful actors. This possibility signals the importance of building redundancy into governance arrangements. Modularity in a polycentric governance system confers such redundancy: when a governance unit or level fails, there are other units or levels to call upon

(Ostrom, 1999). ‘Capture’ of an entire governance system by opponents to transformation is also more challenging when the system is polycentric, due to its dispersal of authority (Marshall & Alexandra, 2016).

Where transition to transformative governance is successfully navigated, and transformation onto a preferred development path is the eventual result, the challenge remains to consolidate the resilience of this path. At this point “the transformative capacity of governance is no longer necessary and becomes dormant, whereas processes of adaptive governance regain primacy” (Chaffin et al., 2017 p. 409).

2.6 Critique

Social scientists have raised a number of concerns about Resilience Thinking and the ambitions of its proponents. Olsson, Jerneck, Thoren, Persson, & O’Byrne (2015) criticized a tendency for RT scholars to discuss resilience as if it were universally desirable, although some such scholars (e.g., Olsson et al., 2014) working within the tradition had already acknowledged this tendency to be misguided. It is now recognised in this tradition that resilience of an SES can involve lock-in to an unsustainable (or otherwise undesirable) development path, and that efforts to weaken this resilience and enable transformation are appropriate in such cases.

The ambitions of RT scholars to integrate the natural and social dimensions of sustainable development have been identified by social scientists as “easily result[ing] in scientific imperialism – which is arguably how resilience theory has been perceived from the perspective of the social sciences” (Olsson et al., 2015 p. 9). A particular criticism of these integrative ambitions relates to methodological differences between the natural sciences and some social science disciplines. Olsson et al. (2015) remarked accordingly on the challenges of resilience becoming accepted as a unifying concept across all social science disciplines, and argued that the ambitions should be wound back from unifying the natural sciences with all social science disciplines to a “middle-range theory” that may be compatible with only some of these disciplines. RT scholars should in this view come to work more pluralistically within inter-disciplinary programs of research into sustainability challenges. While the present chapter focuses on RT as an alternative to the mechanistic methodology under which the dynamics of water management have conventionally been understood, it is acknowledged that this tradition does not offer a panacea for the shortcomings of this management and that insights from other scholarly traditions will also be important.

Olsson et al. (2015) argued also that RT tends to neglect core concerns of certain social science disciplines, including agency and power. Although such concerns were not central in the emergence of resilience thinking (Folke, 2016), they have received increasing attention in this tradition. For instance, agency has been analysed in terms of leadership and entrepreneurship, and power in relation to devolution of authority, co-management, and institutional path dependence (Olsson et al., 2014). RT scholars have concluded that research into polycentric environmental governance will "be strengthened by incorporating power dynamics and addressing the analytic and practical challenges therein" (Morrison et al., 2019 p. 6). Power dynamics of this kind feature in Sect. 5 where the recent history of attempts to transform governance of the MDB's water reform agenda is interrogated.

3 The Murray-Darling Basin

Rivers and their watersheds and floodplains have been identified as SESs (Parsons & Thoms, 2018), as has the MDB (Parsons, Thoms, & Flotemersch, 2017) and its regional subsystems (Marshall & Stafford Smith, 2010). The biophysical subsystem of the MDB SES encompasses the watersheds of two major rivers – the Darling and the Murray – and their many tributary rivers. These rivers flow from the Great Dividing Range across extensive floodplains before discharging to the Great Southern Ocean. There are around 30,000 wetlands within these floodplains, of which 16 are listed under the Ramsar Convention on Wetlands of International Importance. Most of the Basin's area is naturally semi-arid, and it is one of the world's most variable river basins in terms of stream flows and precipitation (Grafton & Horne, 2014).

The watercourses and wetlands of the Basin SES are a source of history, lore and succour for around 70,000 Aboriginal people (Australian Conservation Foundation, 2014). The SES is home more broadly for 2.66 million people. More than one-third of the nation's agricultural production is sourced from the Basin in an average year, including from 9200 irrigated agricultural businesses (Murray-Darling Basin Authority, 2018). Irrigated agriculture typically accounts for around 70% of diversions from the Basin's rivers (Grafton & Wheeler, 2018), but only 2% of the Basin's agricultural area (Grafton et al., 2012). Extensive networks of infrastructure regulate flows in the Basin, with major storages on most rivers. Around 80% of the Basin's wetlands are located on private lands (Office of Environment and Heritage, 2015).

Approved at federation in 1901, the Australian Constitution left state governments with primary control over water policy. The federal (Commonwealth) government nevertheless has leverage in this domain through its constitutional power to enforce international treaties, and from its tax base expanding much faster since federation than that of the states. The MDB is divided between the jurisdictions of four 'Basin states' upstream – Queensland, New South Wales (NSW), Victoria and the Australian Capital Territory – and one, South Australia (SA), at the end of its river system (Marshall, Connell, & Taylor, 2013).

Irrigation development in the MDB commenced in the late nineteenth century on a supply-driven path of controlling water through infrastructure. Like in many other nations, this path was championed by "hydraulic bureaucracies" on a mission described as "a celebration of technology and domination over nature" (Molle, Mollinga, & Wester, 2009 p. 336). This path was emblematic of the conventional management paradigm: "… the future was imagined as a stable state in which pioneering hardship would cease and prosperity descend, with nature now tamed and beneficent" (Stayner & Parsons, 2018 p. 178).

State governments issued new water use licenses throughout most of the twentieth century to increase agricultural production, with most licenses issued during the relatively wet period from the 1950s to the 1990s. Serious problems of water over-extraction emerged when drier conditions returned, requiring the attention of policy makers to shift to managing demand for the Basin's water resources (Wheeler, 2014). By the end of the twentieth century these problems had led to "an alarming level of land and water degradation" (Musgrave, 2008 p. 41). River ecosystem health in 17 of the Basin's 23 valleys was rated as poor or very poor (Davies, Harris, Hillman, & Walker, 2010).

Abel et al. (2016) located the MDB's decision context in the conservation phase of the adaptive cycle, and it appears this context has entered the late stages of this phase wherein the fates of the biophysical and social subsystems of the MDB SES are deeply intertwined. Efforts to increase the Basin's agricultural productivity by tightening control of its surface water systems have led to numerous environmental surprises threatening the productivity and the legitimacy of the irrigation-dominated development path (Marshall & Lobry de Bruyn, 2019). The resilience of the SES has declined, making it increasingly vulnerable to transformation. This vulnerability has been exacerbated by panarchy dynamics, with stakeholders at higher – national and global – levels having come to value more highly the threatened ecosystem services provided by the MDB's rivers and wetlands (Garrick, 2015).

4 Water Policy Reform for Environmental Sustainability in the MDB

4.1 Ongoing Dominance of the Conventional Management Paradigm

Recognition of the consequences of water over-extraction for irrigation development and environmental sustainability led to a succession of attempts to address these consequences through water policy reforms, starting with the national water reform framework agreed to by the Council of Australian Governments in 1994 (Marshall & Alexandra, 2016). For the most part, governments have continued to perceive the dynamics of such reform through the lens of the conventional management paradigm. The effect of such reform has been assumed accordingly to shift water management in the Basin from an existing state to a predictable new, optimal equilibrium. Transition to this optimal state has been assumed to be achievable through controlling a limited number of policy instruments.

This assumed in turn that policy makers could, and would, rationally and comprehensively control implementation of their decisions. However, the degree to which this assumption has been violated in the practice of conventional environmental management led Dovers (1999), in a paper written for the MDB's natural resources policy community, to characterise the norm in this practice as "ad hocery and amnesia. Initiatives are not persisted with and are not firmly institutionalised, policy fashions are changed unthinkingly, and the potential lessons of both success and failure are not sufficiently pursued, absorbed and acted on to improve our capabilities over time" (p. 3).

4.2 The National Plan for Water Security

The most recent round of attempted water policy reform within the Basin was initiated in 2007 by the nation's then Prime Minister announcing a National Plan for Water Security (NPWS) (Australian Government, 2007), subsequently known as Water for the Future. The Commonwealth proposed in this Plan that, with the consent of the Basin states, it would take over responsibility for the MDB's water reform agenda.

The NPWS was intended to overcome inaction by the Basin states on the National Water Initiative which they, with other states and the Commonwealth, had agreed to 3 years earlier. With this Initiative influenced by neoclassical economic theory, environmentally-unsustainable water extraction was understood essentially as a problem of economic inefficiency arising from environmental externalities (Hussey & Dovers, 2006); the solution would involve internalising these externalities through regulation and assigning property rights to the environment, preferably the latter. With this achieved, the Initiative's dominant agenda of establishing a Basin-wide water market to strengthen adaptability within the irrigation sector could be claimed to proceed in the name of both economic efficiency and environmental sustainability.

The grounding of the NPWS in the conventional paradigm's assumption of system controllability was evident from the then Prime Minister's assurance that it would "once and for all" solve the Basin's problem of water over-allocation (Howard, 2007 p. 2). The NPWS led to major reforms: the Water Act 2007 which mandated the Murray-Darling Basin Plan, enacted in 2012, to achieve its objects. These reforms have been hailed internationally as world-leading, with the MDB Royal Commission (Walker, 2019 p. 17) instigated by the SA Government observing that "if the core achievement of the Water Act was preceded by anything similar anywhere else in the world, or for that matter emulated since, this Commission did not discover it".

This core achievement, according to the Royal Commissioner, included a requirement for the Basin's water extraction to be returned to environmentally-sustainable levels. However, the assumption in the conventional management paradigm that such a legislated requirement would be faithfully implemented was overly optimistic. The Royal Commissioner acknowledged the gap between assumed and actual implementation when he expressed "deep pessimism whether the objects and purposes of the Act and Plan will be realized" (Walker, 2019 p. 11). This gap is evident also in Grafton's (2019 p. 135) finding that "little has been achieved to date in terms of Basin-scale environmental improvements" (p. 135).

4.3 Surprising Outcomes of Reform Efforts

Surprise is experienced relative to assumptions of how the world works (Folke, 2016). The gap between assumed and actual implementation of the MDB water reforms can be characterised accordingly in terms of surprise. It is the outcome more precisely of a succession of surprises arising from ad hocery and amnesia in implementing the reforms, as well as from positive-feedback dynamics of institutional path dependence that the mechanistic approach of conventional management assumes away.

These positive-feedback dynamics are driven by actors within the social domain of the MDB SES adapting to (a) the attempts at policy reform, (b) each other's adaptations to these attempts, (c) consequent changes in the ecological domain, and (d) the evolving state of the whole system. The propensity of such dynamics to yield surprises is indicated by Thelen's (1999) observation that adaptation by those disadvantaged by a new institution "may mean biding their time until conditions shift, or it may mean working within the existing framework in pursuit of goals different from – even subversive to – those of the institution's designers" (p. 385). Adaptation of this kind in the MDB case can be understood through an RT lens as concerned with maintaining the Basin's SES in the end stage of its conservation phase by subverting policy reforms that would enable transformation onto an environmentally-sustainable path.

As a first instance of such surprising adaptation in the MDB case, the undertaking in the National Water Initiative for environmental externalities of water extraction to be internalised prior to activation of markets for surface (river) water was soon sidelined by strong advocacy from the farmers' lobby and irrigators' councils (Hussey & Dovers, 2006). Existing surface water rights that could have been reduced without compensation were 'gifted' to irrigators as secure entitlements. Notably, existing rights that had never been exercised, or long been unexercised, were converted fully to entitlements despite persistent warnings that the resulting increased extractions would exacerbate environmental degradation. Moreover, entitlements to surface water were established prior to regulating alternative (e.g., ground) water sources on which interlinked riverine ecosystems also depended. Together with a 'cap' on further MDB surface water extractions agreed by Basin governments in the mid-1990s, the opportunity cost of entitlements arising from their tradability created incentives for irrigators to shift to these alternative water sources, thus further limiting flows to the environment (Marshall & Alexandra, 2016). Crase, O'Keefe, and Dollery (2009) lamented how "the water market that had been so heavily promoted by economists as the vehicle for encouraging water reform played a significant part in exacerbating the over-allocation problem" (p. 444).

The incentives that market activation created for water to be traded to the most profitable enterprises generated surprise also in terms of unforeseen changes in the Basin's pattern of irrigated agricultural production. A former senior officer of the MDBA has reported how water reform in the MDB "resulted in the dominance of two crops – cotton and nuts – replacing a more diverse agricultural base that included fodder, dairy, fruit, vegetables, flood plain grazing and rice. Large, often foreign-owned, agribusinesses are replacing family farms" (Slattery, 2019). Given that collective action by members of a group in lobbying for their common interests tends to be more effective the fewer their number and the more focused their interests, this concentration of economic power within fewer members and industries of the Basin's irrigation sector can be expected to have further increased the sector's influence over implementation of reform initiatives.

It is arguable that the surprises identified above have transformed the MDB SES into a new stability domain from which transformation onto an environmentally-sustainable path has become appreciably more challenging. It can be argued also that these surprises are traceable to the irrigation sector's ongoing success in 'capturing' at least some of the government agencies responsible for ensuring implementation of the water reform agenda. Despite the then Premier of NSW claiming at the outset of water reform deliberations that "the resource departments have largely accepted that they have a wider brief than just promoting the industry sectors for which they are responsible" (N. Greiner quoted in Wettin, 1991 p. 4), there were warnings soon after that state-level authorities responsible for administering water policy had been captured by irrigation interests (Australian Conservation Foundation, 1992).

In response to apparent regulatory capture of significant elements of the earlier phases of the water reform agenda, lobbying by environmental groups resulted in the current, Commonwealth-led, phase of implementing the agenda. This reassignment of responsibility created strong incentives for irrigation interests to broaden their efforts at regulatory capture to encompass the Commonwealth, including the MDB Authority (MDBA) now primarily responsible for implementing the agenda. Success in these efforts is indicated *inter alia* by the 2015 transfer of Ministerial responsibility for the MDBA, and the Basin Plan, from the Commonwealth's environmental portfolio to the agricultural portfolio over which irrigation interests have much greater influence (Horne, 2015). A prompt outcome of this increased influence was the Commonwealth's passing of legislation that placed a 1500 gigalitre (GL) upper limit on acquiring water entitlements for the environment through market purchases, despite such purchases being at least 2.5 times more cost effective, on average, in acquiring a given volume of water than the infrastructure-based water-saving projects (e.g., pipelined irrigation supply systems) favoured by the irrigation lobby (Grafton, 2019).

The NPWS included a commitment "to preserve the integrity of the entitlement system" by establishing "an effective metering, monitoring and compliance system" (Australian Government, 2007 p. 11). Ongoing regulatory capture in at least one

Basin government is suggested by accusations of illegal water extractions in the northern zone of the Basin that only became public due to investigative journalism televised nationally in July 2017. The MDB Royal Commission (Walker, 2019) reported that "perceived lack of enforcement action has produced considerable mistrust in the law and its administration, as well as within communities and amongst Basin States" (p. 67).

Loss of legitimacy of the Commonwealth's water reform agenda is the last surprise to be considered here. In launching the NPWS the then Prime Minister claimed this legitimacy on the basis that Commonwealth was offering to assume responsibility for a water over-allocation problem in the MDB "created entirely on the watch of state governments around Australia … This is our great opportunity to fix a great national problem. It can only be solved if we surmount our parochial differences" (Howard, 2007 p. 6). In contrast, the MDB Royal Commission (Walker, 2019) found that key decisions made by the MDBA in the process of developing and implementing the Basin Plan had been unlawful and/or involved maladministration. It observed also that unchecked non-compliance with the Water Act 2007 and the Basin Plan "brings the law and its administration into disrepute and is likely to hinder its widespread observance. Its largest impact on a Basin-wide scale is on public confidence in the competent management of the Basin's water resources" (p. 51).

Despite Commonwealth claims that implementing the NPWS would overcome the 'parochial differences' of the Basin states, the Royal Commission was left with "concerns about [the MDBA's] genuine commitment to holding Basin States accountable" (ibid., p. 67). The Productivity Commission (2018) found accordingly that implementation of the Basin Plan would be at risk if the compliance functions of the MDBA were not assigned to a new, independent Commonwealth statutory entity. Meanwhile, the Basin Plan has been described as "on a knife edge", with possibilities in play that irrigators or environmental groups will challenge the Basin Plan in the High Court on constitutional grounds, or one or more Basin states will withdraw from its implementation (Keane, 2019).

5 Transforming Governance of the Water Reform Agenda

5.1 Constraints on Adaptive Co-management from Existing Governance

The foregoing account reveals how attempts by MDB policy makers to effect a transition to environmentally sustainable water use in accordance with the conventional approach to natural resources management have repeatedly, and seriously, underestimated the complexity of this undertaking. It is consistent with identification of a need in the RT tradition for an alternative management approach – adaptive co-management – that is predicated on this complexity and its accompanying uncertainty, rather than on conventional assumptions of predictability and controllability.

This alternative approach appears at first glance to have been accommodated in more recent iterations of the water reform agenda, at least in respect of the adaptive management dimension of this approach. Commonwealth and state governments agreed when establishing the National Water Initiative that their frameworks for water property rights and planning would provide for adaptive management of surface and groundwater systems (Council of Australian Governments, 2004). The 'operational' focus for adaptive management that was agreed to is nevertheless distinct from the 'institutional' focus in this chapter on adaptive management of the policy reform process. In any case, what governments have called adaptive management in the MDB has for the most part varied little from conventional management (Allan, 2008). This is despite the resilience concept having been invoked in both the NPWS and the Basin Plan. The outcomes to be achieved by the latter include "productive and resilient water-dependent industries" and "healthy and resilient ecosystems" (Commonwealth of Australia, 2012, clause 5.02(2)).

Status quo governance arrangements have been identified as a key source of the institutional path dependence that continues to constrain management of the MDB water policy reform process in transitioning from the conventional approach to one of adaptive co-management. Stayner and Parsons (2018) argued that for the MDB and northern Australia "substantial shifts in governance and legislation will be required to embed the resilience approach into water management practice, because resilience is not a blanket that can be overlain onto existing structures" (p. 184).

5.2 Proposals for Basin-Wide Transformation of Water Governance

There has been a series of proposals since at least 2003 for MDB water governance arrangements to be transformed in the direction of subsidiarity. These proposals were renewed upon the passage of the Water Act 2007 when primary responsibility for the water reform agenda was centralised to the Commonwealth. Young (2010) argued that a system of environmental water governance designed in accordance with the subsidiarity principle, with regional environmental trusts (non-profit bodies independent of governments) allocated environmental water entitlements they could manage with considerable autonomy, would provide more cost-effective and innovative management of Commonwealth-acquired environmental water than the centralised approach of the Commonwealth Environmental Water Holder (CEWH, responsible under the Water Act 2007 for managing the Commonwealth's environmental water holdings).

Release in 2010 of the *Guide to the Basin Plan* for public consultation brought to a head criticism of what was widely characterised as a centralised approach to developing the Plan. This approach reflected a strong centralising tendency within the Commonwealth that had been evident in its increasing control over the operations of regional natural resource management (NRM) organisations that it had funded on a purchaser-provider basis since at least 2000 (Curtis et al., 2014); there are about 14 such organisations within the MDB (Alexandra, 2019). Proposals to counter centralisation of the water reform process by establishing regional environmental water trusts continued to be argued; e.g., with Campbell (2010) arguing that

> locally-driven environmental watering [i.e., water delivery] plans can more easily capture opportunities, better meet environmental needs, and better manage third-party impacts. Working with Landcare and catchment groups, environmental water managers can complement activities such as weed and pest control, or revegetation works, to deliver multiple benefits for river health, biodiversity and salinity management. (para. 23)

In contrast, the Commonwealth's Productivity Commission (2010) recommended that any devolved governance arrangements for environmental water management build on the regionalised arrangements for NRM governance. Although this strategy may have been less risky for the Commonwealth, its contribution towards effective subsidiarity would have been much less than envisaged by Campbell given the limited autonomy of regional NRM organisations (Ryan, Broderick, Sneddon, & Andrews, 2010), and the limited autonomy they typically allowed Landcare and other local action groups that depended on them for funding (Campbell, 2016). Power relations and mental models embedded in status quo governance thus served to dilute proposals for transformative devolution of environmental water management such that the outcomes would have been adaptive at best. In any case, the Productivity Commission's proposal was not implemented, at least partly due to concerns regarding the technical capacities of regional NRM organisations to take on responsibilities for environmental water management (Cummins & Watson, 2012).

5.3 Bridging Organisations, Panarchy, and Emergence of Transformative Governance

Transformation of MDB environmental water governance nevertheless appears to be underway as a result of a series of small, lower-level transformations that commenced over a quarter of a century ago. The NSW Murray Wetlands Working Group (MWWG, later becoming the Murray-Darling Basin Wetlands Working Group or MDWWG) was established in 1992 as an local initiative of the Murray and Lower Murray Darling Catchment[2] Management Committees (Nias, Alexander, & Herring, 2003). Its purpose was to develop and implement technically-sound and community-endorsed plans to improve management of wetlands in these catchments "by linking community involvement with best scientific understanding" (MDWWG, 2017). Its

[2] Synonymous with 'watershed'.

20 members included representatives from community, industry, government, catchment management committees, science, and the former MDB Commission.

Over 2000–2009 the NSW Government entrusted the MWWG with responsibility for managing two environmental water licenses amounting to 32 GL that this government had created from water-saving projects in the area of operation of Murray Irrigation Limited (Murray Irrigation) (Bowen & Nias, 2008). In a trial project to support rehabilitation of remnant wetland areas within that area, the MWWG worked with Murray Irrigation, its shareholders (irrigators supplied through its infrastructure), and the NSW Government to deliver water via irrigation infrastructure to wetlands on voluntarily-participating private properties. Prior discussions had identified that "some landholders were nervous at the idea of working with 'greenies' and were concerned that we may start dictating how they might manage their properties" (Nias et al., 2003 p. 7). However, numerous Murray Irrigation irrigators contacted the MWWG, after the trial, to ask about participating in a similar project. Over 2000–2006 it managed projects which engaged 131 private landholders and diverted 82.5 GL into wetlands on private properties within these catchments (Nias & Jones, 2012).

In 2009, with environmental water acquisition being massively scaled up under the Water for the Future program, responsibility for the environmental watering programs established by the MWWG was taken over by the NSW Government's environmental agency. Like other NGOs that had become involved with environmental water, the MWWG had to reconsider its role given the escalation of government activity in that domain. It was one of six NGOs that established the Water Trust[3] Alliance in 2010 to "build constructive associations between water trusts and governments, landowners, business and community groups to optimise the effectiveness of environmental water management" (Siebentritt, 2012 p. ii). Other Alliance members were: Australian Conservation Foundation; Environmental Water Trust; Healthy Rivers Australia; Murray-Darling Association (of local governments); and the Nature Foundation SA.

A workshop convened by the Alliance in late 2011 found that although NGOs had successfully achieved community buy-in to environmental water programs, they faced irrelevance unless they focused on "how to increase their maturity and capacity for commercial and legally recognised operations …" (Siebentritt, 2012 p. 24). This need had been anticipated by the MWWG when in 2009 it started to work under a corporate structure, and by its successor the MDWWG which acquired the Environmental Water Trust to partner with The Nature Conservancy in establishing the MDB Balanced Water Fund.

The Environmental Water Trust was established in 2007 as a national non-government charitable organisation to facilitate investment in the long-term health of Australia's wetlands and rivers. The Balanced Water Fund "enables traditional, capital market investors to support large-scale, long-term conservation works while

[3] 'Water trust' referred loosely to NGOs involved in acquiring or managing water for environmental purposes.

diversifying their portfolio and earning income through investment in the Australian water market" (Carr, Nias, Fitzsimmons, & Gilmore, 2016 p. 269). It is anticipated that 20% of the water assets acquired by the Fund will on average be donated to the Environmental Water Trust for environmental watering in the MDB, primarily of wetlands on private land. The Fund also donates cash to the Trust to cover the MDWWG's costs in conducting environmental watering on its behalf. A representative of The Nature Conservancy quoted in Marshall (2017) viewed its role as catalytic, intending that after 10 years "things like the Balanced Water Fund are a matter of course, and there's no longer a need for us to be involved" (p. 200).

Recognising the challenges faced by the CEWH in delivering water to wetlands on private lands, the MDWWG approached it with a proposal to manage a portion of its water similarly to its prior arrangement with the NSW Government. The CEWH was interested but the idea stalled in the absence of a commitment to covering the MDWWG's costs in performing this role. As explained by a representative of the Nature Fund SA quoted in Marshall (2017), this NGO was prepared to "take the water and then bargain after the event" (p. 196). This strategy paid off, with the CEWH ultimately agreeing to a five-year partnership agreement with the Nature Fund SA (CEWH & Nature Fund SA, 2012) under which they would deliver up to 50 GL of the CEWH's water to smaller wetlands and floodplains along the lower Murray River (CEWH & Nature Fund SA, 2012).

The Nature Fund SA's strategy of starting small and building trust incrementally was successful: "From fighting every step of the way initially … there [has been] a huge change in the level of trust, and therefore the level of flexibility that we have" (Nature Fund SA representative quoted in Marshall, 2017 p. 197). During this process the Nature Fund SA mentored other NGOs also based in the lower Murray region of South Australia – the Ngarrindjeri Regional Authority (the peak organisation of the Ngarrindjeri Indigenous Nation) and the Renmark Irrigation Trust – that were looking to develop their own capacities for environmental water management. The CEWH subsequently instituted partnership agreements, similar to that established with the Nature Fund SA, with each of these two other NGOs. The then incumbent in the CEWH position[4] envisaged partnerships of this kind being replicated across the MDB:

> My longer-term ambition would be to have examples of those agreements across the Basin, across all the jurisdictions. … Things will change in ways that we can't predict, so that's why we're trying to be very open to approaches from non-government organisations and individuals in this. I see these things, with appropriate limitations imposed by legislative responsibilities and resourcing implications, growing in spread and value. … My understanding is evolving with my experience of it; so I'm seeing it already being more powerful than I thought it could be. … I just want a system that allows that evolution, builds the capacity of the non-government groups, gets us to the point where we're not so risk averse. (Marshall, 2017 p. 200)

We see in this account how cross-level dynamics of panarchy have enabled transformation of a significant and growing share of environmental water governance in

[4] David Papps.

the MDB despite constraints on all-at-once Basin-wide transformation arising from institutional path dependence. Local entrepreneurship by NGOs, as bridging organisations, established a foundation for higher-level governance innovations in raising funds for NGO involvement in environmental watering and managing such watering. Grounded in the subsidiarity principle, the emerging governance arrangements are conducive to the informed experimentation and power-sharing of adaptive co-management. Success of this management approach in expanding the reach and effectiveness of environmental watering programs, and strengthening their legitimacy, is weakening the hold of the conventional management paradigm. This effect is not limited to the CEWH; for instance, a representative of the NSW Government agency responsible for environmental water management stated:

> We're starting to loosen the reins a little bit. Particularly … in engaging with environmental trusts and conservancies and the like, because they often have the ability to do more than just play with the water; they can do revegetation programs, or fencing, or stock removal or whatever. And in some instances they can have better relationships with the landholders as well … (Marshall, 2017 p. 204)

The emergent transformation that has occurred in governance of CEWH-held water is particularly significant in the present context of increasing doubts that governance arrangements for the Basin Plan will be capable – with the MDBA's legitimacy diminished by recent events, and support from some Basin state governments remaining questionable – of securing its implementation (Alexandra, 2019). Marshall et al. (2013) anticipated this scenario when predicting that CEWH-held water would come to supplant the Basin Plan as the centrepiece of the MDB's high-level water policy and management system:

> The Commonwealth is likely to acquire sufficient water entitlements under its direct control … to be able to achieve most of the environmental targets of the Basin Plan even if the states withhold their support. … It is likely therefore that in coming years the CEWH will emerge as the most important water management institution in the MDB. (p. 210, 212)

If this prediction holds true, then the transformation occurring in governance of CEWH-held water has significance not only for management of environmental water across the MDB but also for higher-level processes of water policy reform. The spread of adaptive co-management of environmental water under such a scenario may normalise the approach to a degree that policy makers come increasingly to acknowledge its advantages in their realm over the conventional approach assuming predictability and controllability.

6 Conclusion

This chapter explored how insights from RT can better inform efforts to reform water policies consistently with requirements for sustainable development. The focus was on the Murray-Darling Basin (MDB) in Australia, and particularly on reforms seeking to achieve environmentally sustainable water use. We found that this reform process remains dominated by a conventional, command-and-control, management approach that asserts predictability yet repeatedly delivers uncertainty in its place. In contrast, the RT approach to water policy reform in the MDB would involve adaptive co-management. This approach would avoid those surprises arising from the conventional approach's misguided confidence in the predictability and controllability of the reform process, while being fit-for-purpose in dealing with the irreducible uncertainty of outcomes from intervening in the Basin's complex social-ecological dynamics.

An RT perspective highlights that shifting to adaptive co-management of the reform process would require transformation of the governance arrangements that evolved to support the conventional management approach. The MDB experience reveals that it is possible for such transformation to emerge through the cross-level dynamics associated with the resilience approach's concept of panarchy. Local-level entrepreneurship by NGOs (as organisations bridging governments and local communities) in environmental water management has in this case established a foundation from which transformative governance of the Basin's sustainability-driven water reform agenda continues to evolve. We conclude that RT can, working pluralistically with other scholarly traditions, make important contributions to understanding how ongoing challenges in reforming water policy for sustainable development might effectively be overcome.

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Reducing Nutrient Loading from Agriculture to Lake Ecosystems – Contributions of Resilience Principles

Kate H. Reilly, Elena M. Bennett, Jan F. Adamowski, and Gordon M. Hickey

Abstract Nutrient loading from agriculture is a critical threat to aquatic ecosystems, affecting their ability to provide safe drinking water, and limiting the provision of ecosystem services such as water-based recreation. Efforts to manage the problem typically focus on encouraging, incentivising, or requiring use of best management practices to reduce nutrient inputs on farms and limit their transport to water systems. For example, protecting and restoring wetlands and riparian ecosystems, which filter nutrients from run off and offer co-benefits such as carbon sequestration, terrestrial and in-stream habitat, and recreational opportunities, are important strategies. However, in many agricultural catchments, nutrient concentrations in waterbodies remain high despite such interventions. Reasons for this are myriad and include low uptake of best management practices on farms, timelags in ecosystem response, legacy phosphorus stored in soil and lake sediments, and changing weather patterns associated with climate change. This chapter explores the potential contributions of resilience thinking to reducing nutrient loading to waterbodies and minimising its impacts by treating agricultural watersheds as social-ecological systems, recognising the pressures on freshwater ecosystems caused by human activities throughout the watershed as well as the reliance of such activities on functioning aquatic ecosystems and the services they provide. This involves more explicitly accounting for interactions within agricultural social-ecological systems, planning at the catchment scale, adaptive management, and new governance arrangements. We draw on some lessons learned from a range of innovations developed for technical management practices, policy and governance approaches. We translate these lessons into pathways for reduced nutrient loading for sustainable management of lakes in the face of changing climate, degrading aquatic ecosystems and increasing demand for land and food.

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1 Introduction

Nutrient loading in watercourses is a persistent and widespread pressure on freshwater ecosystems and the services they provide (Carpenter et al., 1998; Smil, 2000). Lake ecosystems are particularly affected by elevated phosphorus and nitrogen concentrations, which can lead to eutrophication (Azavedo, van Zelm, Leuven, Hendriks, & Huijbregts, 2015). Eutrophic lakes typically have increased algal biomass, which can sometimes contain neuro- and hepato-toxins that are dangerous to people and their pets. The decomposition of this biomass leads to reduced aquatic oxygen concentrations and fish kills (Anderson, Glibert, & Burkholder, 2002; Smith, 2003). Lakes often undergo a regime shift from clear-water to turbid or eutrophic states, which persist due to the release of phosphorus from sediments as the bottom of the water deoxygenates after eutrophication begins; research shows that it is nearly impossible to return lakes to a clear water state (Carpenter, 2005; Folke et al., 2004; Scheffer & Carpenter, 2003). The presence of algal biomass often hinders access to lakes for recreation, reduces availability of fish for food and recreational fishing, creates human health risks, and increases the cost of drinking water treatment (Carpenter et al., 1998).

Agriculture is a major source of nutrient loading in lakes, as nitrogen and phosphorus from fertiliser applications and manure are transported to watercourses in surface and subsurface runoff (Heathwaite & Dils, 2000). Due to its ecological, social and economic effects, reducing nutrient transport to watercourses is considered an important policy goal in most OECD countries, as reflected in the European Union (EU) Water Framework Directive (WFD), for example. While efforts to reduce nutrient transport have had some success in reducing loading, nutrient levels in freshwater ecosystems generally remain high (Parris, 2011). For example, phosphorus concentrations in EU lakes were reported to have declined by 0.8% per year between 1992 and 2012 (European Economic Area [EEA], 2015a), yet more than 40% of EU rivers and lakes remain affected by pollution from agriculture. In some areas, including the Netherlands, Belgium and southern Italy, over 90% of waterbodies are affected (EEA, 2015b). In North America, Lake Erie is a prominent example of algal bloom development due to nutrient loading from agriculture in its watershed (Bosch, Evans, Scavia, & Allan, 2014).

A common strategy to reduce nutrient transport resulting from agricultural activities is to require or encourage the use of technical measures, often referred to as best management practices (BMPs) (Kleinman et al., 2015). Such BMPs can include the use of management practices to reduce the likelihood of nutrient loss from soil, such as changing the timing of fertiliser application to avoid wet seasons, limiting applications to meet crop needs only in order to avoid soil saturation, and improving manure storage. Transport of nutrients from agricultural fields can also be mitigated using vegetated riparian buffer strips or constructed wetlands, designed to trap and retain nutrients before they reach watercourses. In some jurisdictions, the use of certain BMPs on farms is required by law, while in others they may be a condition of receiving agricultural supports and subsidies. In some cases, such as in the EU under the WFD, management plans for watersheds must describe a programme of measures to reduce nutrient loading.

Despite such policy interventions, nutrient loading to lakes persists and the recovery of lake ecosystems following reductions in nutrient inputs is slow (Bootsma, Barendregt, & van Alphen, 1999; McCrackin, Jones, Jones, & Moreno-Mateos, 2017). Resilience thinking may offer new opportunities for agricultural policy design, through its emphasis on taking a system-wide approach to managing nutrient loading, focusing on flexible and adaptive interventions and on enhancing ecosystems' capacity to absorb stressors. It also puts the focus on better managing the social and ecological interactions that are known to hinder progress, rather than relying solely on technical measures. This chapter explores the causes of continued nutrient loading, particularly phosphorus (Schindler, 2012), to lakes and the lack of response of lake ecosystems to efforts to reduce nutrient loading. Based on this analysis, the potential contributions of resilience principles to the management of agriculture and lake ecosystems are assessed.

2 Understanding the Persistence of Nutrient Loading from Agriculture to Lake Ecosystems

2.1 Policy and BMP Implementation

2.1.1 BMP Effectiveness

Applications of fertiliser and manure to agricultural land have contributed to the intensification of agricultural production and the increased yields that are required to feed the growing world population (Foley et al., 2011). To maintain these yields while reducing nutrient pollution, it becomes necessary to manage nutrient inputs in the regions that experience nutrient surpluses – primarily, the USA, western Europe, China and northern India – and reduce their transportation to watercourses (Foley et al., 2011; Schröder, Smit, Cordell, & Rosemarin, 2011). The BMPs commonly used to achieve this vary in their effectiveness; studies of the impact of BMPs on water chemistry have found reductions in phosphorus and nitrogen compounds of 0 to over 90% (Kroll & Oakland, 2019). Factors such as soil type, climate, local vegetation, installation and design, as well as the timing and magnitude of storm events, season and other land uses in the watershed, influence pollutant removal efficiencies (Kleinman, Sharpley, Buda, McDowell, & Allen, 2011; Liu et al., 2017; Sharpley, Kleinman, Flaten, & Buda, 2011).

Assessing the performance of BMPs in varying conditions is essential for identifying effective solutions for a given circumstance, but it is also challenging to achieve and relies on feedbacks between scientific understandings of the biophysical processes involved and 'on the ground' BMP implementation practices (Kleinman et al., 2015). Long-term monitoring of implemented BMPs is therefore particularly important (Easton, Walter, & Steenhuis, 2008; Liu et al., 2017). Without long-term data, only short-term effectiveness can be assessed, which fails to account for the tendency of BMPs' removal capacity to decline over time due to the need for maintenance, accumulation of pollutants, and other factors (Liu et al., 2017; Uusi-Kämppä & Jauhiainen, 2010). This decline in BMP efficiency over time is compounded by the legacy effects of agricultural practices. For example, even if inputs to a soil with high phosphorus concentrations are stopped, it may take hundreds of years for the soil phosphorus concentration to reduce to expected levels. This slow release of phosphorus from soils to runoff and thereafter to lakes is a key cause of the persistence of lakes' eutrophic state despite successful prevention of new nutrient additions in agriculture (Carpenter, 2005; Meals, Dressing, & Davenport, 2010). Therefore, a short-term focus on BMP implementation may limit the potential to address longer-term dynamics affecting water quality.

2.1.2 Policies

Policy instruments that aim to increase on-farm implementation of BMPs include voluntary programmes for farmers, regulation, and market-based instruments, as well as combinations of these tools (Kleinman et al., 2015). In North America, voluntary programmes are common, such as the 4R certification programme around the Great Lakes. The 4R programme (Right rate, Right time, Right place and Right source) is a science-based voluntary initiative to improve nutrient stewardship, in which third party auditors assess implementation of the programme's 41 criteria by agricultural retailers and nutrient service providers. In 2016, it was found that 40% of the farmland in the western Lake Erie Basin was influenced by certified providers (Vollmer-Sanders, Allman, Busdeker, Moody, & Stanley, 2016).

In the EU, the WFD provides a legal requirement to ensure the ecological quality of freshwater bodies, which includes targets for phosphorus and nitrogen concentrations. Nitrate vulnerable zones are required to be defined under the associated Nitrates Directive. These legal requirements for water quality provide the basis for local measures to reduce loading, generally incorporated into the required River Basin Management Plans. The EU Common Agricultural Policy provides a means to require and incentivise farmers to invest in BMPs – to some extent use of BMPs is required as a condition for receiving agricultural subsidies (part of the Good Agricultural and Environmental Condition requirements for receiving direct payments) (European Commission, n.d.). The Rural Development Programme allows EU Member States to implement other agri-environmental schemes that compensate farmers for the increased cost of BMP implementation (Parris, 2011). Some jurisdictions go further and make their use a legal requirement. For example, the entirety of Northern Ireland is defined as a 'nitrate vulnerable zone', for which the Northern Ireland Phosphorus Regulations restrict fertiliser applications in time and space and require certain standards of manure and livestock management.

Tradeable permits and taxes are also possible but are less widely used than voluntary and regulatory responses (Kleinman et al., 2015). Of the various policy approaches, an analysis of policy to reduce phosphorus loading found that a mixture of mandatory regulations and voluntary measures can be effective in making targeted reductions at the scale of the farm or a small watershed.

2.2 Factors Hindering the Effectiveness of BMP-Focused Policy

While these technical and policy responses have had some success in reducing nutrient concentrations in freshwater bodies, at a global level, transport to water courses has increased over the last century (Beusen, Bouwman, Van Beek, Mogollón, & Middelburg, 2016). We can consider four main factors that limit the effectiveness of existing responses – policy and management plan design, farmer uptake, enforcement of regulations, and scale mismatches.

2.2.1 Challenges in Achieving Sufficient BMP Implementation Across Watersheds

Lakes are the receptacle for nutrients originating from land across their upstream watershed. The land uses, land cover, transport capacity (influenced by hydrological, geological and topographical factors), and land management vary spatially within the watershed (Fraterrigo & Downing, 2008; Sharpley et al., 2011). This means that different locations for BMP implementation within a watershed, or even within a farm, do not produce equal results in terms of alleviation of nutrient losses. For example, a study of the Petzenkirchen catchment in Austria and Lake Vico in Italy found that small areas of land within each watershed produced disproportionately more nutrient pollution than others (Strauss et al., 2007). Such critical source areas typically have high concentrations of phosphorus in the soil and are hydrologically connected to the waterbody, because of steep slopes, presence of rills and gullies, proximity to the waterbody and other factors (Sharpley et al., 2011). Therefore, focusing BMP implementation on the critical source areas produces improvements in water quality more cost effectively than more indiscriminate implementation throughout a watershed (Arabi, Govindaraju, & Hantush, 2006; Strauss et al., 2007).

To achieve spatial optimisation of BMP implementation within a watershed, good quality, watershed-level data on the factors that determine critical source areas is needed, as well as understanding of the hydrological processes involved (May et al., 2019; Sharpley et al., 2011). Integration of spatial prioritisation into policy requires good linking of measures taken at different levels. A watershed plan can indicate spatial locations for priority BMP implementation, but this may require sufficient flexibility in national or subnational agricultural policies to require or incentivise farmers to put them into practice.

The areal extent of BMPs implemented within a watershed's critical source areas or other vulnerable locations is also considered critical to maximise their effectiveness (Rao et al., 2009; Scavia et al., 2017). However, due to the large number of farms and their diffuse distribution, achieving adequate coverage is often more of a challenge than ensuring the technical effectiveness of the measures themselves (Kleinman et al., 2015). For example, a study of watersheds feeding Lake Erie found that application of BMPs, including use of cover crops, sub-surface fertiliser applications and buffer strips, in targeted locations on 50% of cropland only came close to meeting the required 40% reduction in phosphorus loads (Scavia et al., 2017). Measures to promote BMP uptake by farmers, particularly on land that is a critical source area or adjacent to a waterbody, remain a priority.

2.2.2 Farmer Uptake

In jurisdictions that rely on voluntary action (or where regulations are poorly enforced), farmer behaviour change is key. Changing behaviour is challenging, particularly where the new behaviour can incur considerable costs – for example, through loss of productive land, installation of fencing and other interventions, and potentially lower yields. In some jurisdictions, such as under the EU Common Agricultural Policy, these costs can be compensated by subsidies. Alternatively, and generally preferably, farmers can recuperate costs by improving fertiliser efficiency or though income diversification (e.g. cultivation of alternative crops, such as willow, on buffer strips).

However, there are more factors at play than the financial cost of BMP implementation and the availability of subsidies or other financial incentives. These factors can be broadly categorised as information and awareness; social norms; demographics, knowledge and attitudes of farmers; farmers' risk and time preferences; farmers' environmental awareness; farm type; and characteristics of the BMPs (Liu, Bruins, & Heberling, 2018; Prokopy et al., 2019; Winter et al., 2017). For example, a study of farmers' attitudes in northwest Ohio towards BMPs that reduce nutrient inputs to Lake Erie found that perception of risks to profit and the environment from poor water quality was most consistently associated with positive attitudes to implementing BMPs. For some farmers, however, a perception that their use of BMPs could have a positive impact on water quality was more important (Wilson, Howard, & Burnett, 2014). Similarly, changing farming practices can represent a risk to yield and therefore income. Hence, before they put a change in place, farmers need to feel confident in its effectiveness, in their ability to implement it (Wilson, Schlea, Boles, & Redder, 2018) and that it will not negatively affect their profits. A study of dryland farmers in Australia found that farmers' skills and abilities and a sense of control of their own destiny, amongst other factors, were predictors of pro-environmental land management on their farms (Price & Leviston, 2014). These and other studies suggest that the economics, psychology and sociology of individual farmers and farming communities can be as, if not more, important in agricultural nutrient management efforts than technical solutions.

Understanding these factors becomes particularly critical in jurisdictions that rely on voluntary action.

2.2.3 Enforcement of Regulations

In many jurisdictions, measures to reduce nutrient loading from agriculture are required either by regulations or as a condition for accessing government support and subsidies. Perhaps not surprisingly, in many cases enforcement of requirements is required for farmer compliance. For example, phosphorus loading to Lake Champlain, Vermont, US, has continued despite large investments in reduction programmes to meet state-wide Water Quality Standards and the local limit for phosphorus concentration in Missisquoi Bay of 25 ug/L under the terms of a bilateral agreement between Vermont and Quebec, Canada. Insufficient enforcement of these regulations has been blamed for this situation, with political reluctance to tackle small farms and to allocate funding for compliance due to pressure from other economic interests considered the main obstacles (Osherenko, 2014). There are also practical, social and political difficulties associated with enforcing farm-scale compliance through regulation, largely due to private property rights and limits on government resources and jurisdiction. An approach trialled in Canterbury, New Zealand, used models to calculate on-farm nutrient losses and enforce limits on nutrient pollution on the basis that farm-scale compliance contributes to achieving nutrient objectives at a watershed scale (Duncan, 2014; Wheeler, Ledgard, Klein, Monaghan, & Carey, 2003). This approach experienced difficulties in practice, however, as the legal and administrative frameworks in place were not able to accommodate advances in the science underlying the model. Shifts in the set limits led to farmers needing to invest more in BMPs than had been planned for, and the products of the model were open to interpretation as to whether limits were complied with (Duncan, 2014). These examples highlight the complexity of appropriate regulatory design and enforcement, including social acceptance, political will, suitable legal frameworks, and the need for achieving a balance between adapting to uncertainty and providing sufficient certainty for farmers to feel confident investing. Achieving this balance will inevitably raise some difficult policy questions concerning the economics of industrialised agricultural systems, the potential limits to private property rights in rural landscapes, and the role of government in supporting agriculture.

2.2.4 Scale Mismatches

The processes that both drive and are used to manage nutrient loading from agriculture occur across multiple levels and scales, leading to complex interactions and interdependencies between them. The processes that influence nutrient loading from agriculture operate at multiple spatial scales, from farm to global. As previously mentioned, the extent to which nutrients are transported from the farm to the watercourse is site dependent, with very local variations in soil and vegetation cover affecting the proportion of nutrients transported in surface and subsurface runoff. For example, nutrient leaching from soils can occur in deep sandy or organic, phosphorus-saturated and/or waterlogged soils, and subsurface transportation is more common in artificially drained fields. Surface runoff is also affected by a variety of factors, including vegetation cover, slope, timing and type of fertiliser application, rainfall and temperature, some of which vary at field level, while others, such as rainfall, may vary at watershed level (McDowell, Sharpley, Condron, Haygarth, & Brookes, 2001). Also at a watershed level, watercourses are the receptable for nutrients originating from farms and other land uses throughout their watersheds (Mander, Kull, Kuusemets, & Tamm, 2000). Furthermore, global climate change is altering precipitation patterns, in terms of magnitude, frequency and seasonality of rain events, which affect nutrient transportation in runoff. These alterations and their effects vary regionally, or even between watersheds (Bosch et al., 2014; Jeppesen et al., 2009). For example, climate change is predicted to accelerate nutrient export from agricultural watersheds around Lake Erie (Bosch et al., 2014). The warmer temperatures in lakes caused by global climate change is also expected to increase internal loading from sediments and alter species composition (Jeppesen et al., 2009). Therefore, the rate of nutrient loading to any given watercourse is controlled by processes occurring at sub-field to global levels.

These cross-level interactions between the biophysical processes driving nutrient loading and its effects result in scale mismatches with its management and governance (Cash et al., 2006). At a basic level, the jurisdictions responsible for agricultural and water policy are often at a national or subnational level, whereas the management actions required are implemented at a farm level and require sufficient coverage at a watershed level. Decision making at watershed level, such as nutrient reduction measures in watershed management plans, must aim to reach a threshold in BMP implementation that achieves the desired improvements in water quality while taking into account the differing contributions of individual farms and farm-level constraints in BMP adoption (Gibbons & Ramsden, 2008).

There are also temporal scale mismatches in the problem and its management. Even if interventions to reduce nutrient loading from agriculture are successful, recovery of lake ecosystems is often slow. Phosphorus inputs constitute a stress to lake ecosystems, which affect many other ecosystem parameters including turbidity, biomass and species composition. The shift to a turbid state is often sudden once a threshold in phosphorus concentration is passed or as continuing stress from phosphorus makes the system more vulnerable to other perturbations, such as storms (Scheffer, Brock, & Westley, 2000). Once shifted to a turbid regime, lakes are often resistant to recovery efforts and to the cessation of nutrient inputs, or revert to a turbid state following short term improvement, with the consequent ecological and socio-economic impacts (Søndergaard et al., 2007).

Overall, then, the problem of nutrient loading to aquatic ecosystems, particularly lakes, from agriculture is a complex, multi-faceted problem. It can be tackled at a variety of levels, from technical optimisation of BMPs and biomanipulation of lakes, to regulations including standards, subsidies and voluntary agreements. The implementation of these management measures, policy responses and investments is challenging due to the large and diffuse number of farmers within a watershed and the often slow or non-existent response of ecosystems to the efforts. Furthermore, the political, social and economic barriers to addressing nutrient loading are location specific according to culture, history and the social and economic realities in any given place, and hence policies to address them will necessarily vary between jurisdictions (McDowell et al., 2016). Nevertheless, clear water lakes produce numerous benefits to human wellbeing and society, including recreation and other cultural ecosystem services, and support biodiversity (Ruckelshaus et al., 2013). More efficient, integrative and effective strategies are therefore required.

2.3 Contributions of Resilience Thinking

Current efforts to reduce nutrient loading to lakes and manage its consequences are clearly insufficient, particularly as both nutrient loading and eutrophication are expected to increase with climate change (Jeppesen et al., 2009). The new paradigm of water resilience is gaining increasing attention in policy and practice as a new approach to this problem, moving towards inclusive, adaptive and polycentric management and governance.

As outlined in chapter "The Emergence of Water Resilience: An Introduction" of this volume, water resilience is based on the understanding of water systems as social-ecological systems, with multiple complex and dynamic interactions between the social and ecological components. Under this paradigm, change and uncertainty are accepted as the norm; the goal is to sustain the social-ecological systems in a desirable state by coping with and adapting to change, rather than seeking to prevent it. This involves sustaining their functions where possible, adapting them to change, and transforming them if necessary.

There are several characteristics of management and governance of water for resilience (Fig. 1). The focus is on the interactions across scales of the ecological and social components with each other and with external factors, including feedbacks, thresholds and interdependence, which influence the behaviour of the social-ecological system (Folke et al., 2010). Diverse and inclusive participation that enhances social learning is critical; it allows various types of knowledge and mental models of the system to influence decision making and helps to build the trust necessary for collaborative action (Lebel et al., 2006; Olsson, Folke, & Berkes, 2004). Planning processes and institutional arrangements should be flexible and polycentric, which allow location-specific decision making combined with responses across scales and sectors (Pahl-Wostl, Lebel, Knieper, & Nikitina, 2012). These characteristics facilitate the use of adaptive management and adaptive governance, meaning that management and governance can adjust to new knowledge about the system, as well as changes and surprises. An emphasis on incorporating a wide range of ecosystem services and precautionary approaches to risk assessment are also essential (Plummer & Baird, this volume).

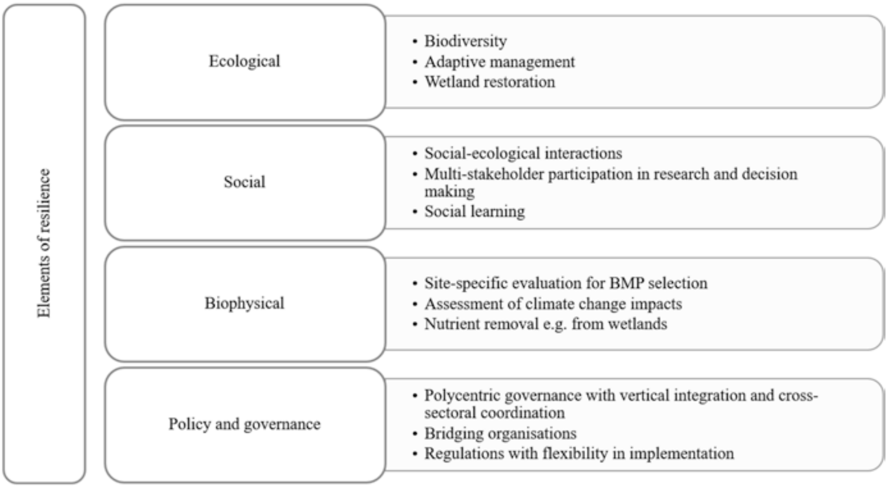

Fig. 1 Elements of resilience explored in this context

In the case of managing nutrient loading from agriculture, a governance and management approach based on resilience moves away from 'command and control' or incentive-based responses to nutrient pollution as a single problem with a single solution. It instead focuses on systems thinking, based on developing understanding of the interactions between variables and the complexity and uncertainty inherent in managing water quality, which will increase with climate change (Ulrich, Malley, & Watts, 2015). The emphasis is on tackling the slow variables, such as the phosphorus stored in watershed soils and lake sediments, that gradually reduce resilience of lake ecosystems, moving the system closer to the tipping point at which it shifts to a eutrophic state, rather than the disturbance event that triggers the regime shift (Carpenter, 2005; Folke et al., 2004). A collective shift towards a resilience approach is necessary for managing nutrient pollution in lake ecosystems due to the insufficient progress of the approaches taken to date, the finite nature of phosphorus resources, the growing pressure on the food production system from the increasing global population and the need to preserve land for natural ecosystems, the increased value placed on the ecosystem services that lakes provide, and the changing climate.

Basing management of nutrient loading on a resilience approach requires adjustments to governance, institutions and policy. Agricultural water management and policy in Australia, for example, is increasingly based on resilience thinking (Ayre & Nettle, 2017; Pittock, Williams, Grafton, & Director, 2015; Walker, Abel, Anderies, & Ryan, 2009). For example, an analysis of how a shift toward greater resilience could be achieved in practice was conducted in the Goulburn-Broken catchment in Australia, which is affected by problems of water withdrawals and nutrient loading. It was suggested that management could be enhanced by resilience thinking in several ways, including incentivising farmers that contribute to resilience (constructed wetlands, improving off-farm water quality), eliminating incentives for farmers that reduce resilience (e.g. those with over-reliance on irrigation), enhancing connectivity of natural ecosystems (e.g. riparian and wetland ecosystems) through competitive auctions (e.g. to increase the area planted with native vegetation), making long-term investments in resilience independent of short-term political cycles (e.g. using environmental trust funds), devolving resources and decision making capacity to appropriate scale (polycentric governance), and promoting through information/rules/incentives a shift in mental models away from unachievable stability towards adaptive capacity. Transforming the system would require evidence that the current state is untenable and undesirable, political will, recognition of need for change, effective leadership and trust, support for those who lose out, and strategic disinvestment in policies and management measures that promote the current state (Walker et al., 2009). This example from Australia illustrates several of the key components of a resilience-centred approach to managing nutrients in freshwater ecosystems, namely policy coherence, long-term thinking, polycentric governance and greater attention to psychological characteristics of the relevant actors across scales.

2.3.1 Social-Ecological Interactions

Agricultural watersheds consist of several ecosystems, social systems and economic activities, including agricultural, riparian, river and lake ecosystems; farm businesses; recreational and tourism users and businesses benefitting from lake ecosystem services; drinking water providers; and several others less relevant to the topic of nutrient loading. They are also affected by external factors such as higher-level policy and economic dynamics. The resilience of the social-ecological watershed system relies on the resilience of its various components.

Resilient farm businesses with sufficient profit margins are more able to invest in BMPs and more willing to tolerate some loss of production, which will in turn reduce stressors to freshwater ecosystems (McDowell et al., 2016). Furthermore, a more efficient use of mineral fertilisers makes farm businesses less vulnerable to price fluctuations due to supply limitations of the phosphate rock used in such fertilisers (Ulrich et al., 2015). Resilient lake ecosystems, which have sufficient species and functional group diversity, are less vulnerable to the effects of stressors, including nutrient pollution and climate change. They are less likely to shift regime into a turbid, eutrophic state and therefore can maintain biodiversity and provision of ecosystem services, including clean water and recreation (Folke et al., 2004).

There are various dynamic interactions within and between these ecological, social and economic systems that must be accounted for in managing nutrient loading. For example, clear water lakes with abundant fish species are attractive for anglers, who can otherwise be physically impeded from fishing in turbid, eutrophic lakes with algal blooms. However, fish bait introduces additional nutrients to the system. Fish stocking of recreational lakes can accelerate nutrient release from sediments to the water column and can increase algal abundance due to predation of grazers, depending on the species introduced (Borics et al., 2013).

2.3.2 Flexible Institutions and Polycentric Governance

Policy responses to the problem of nutrient loading in freshwater ecosystems are often complex and overlapping. The governance of water systems is affected by decision making in the arenas of agricultural, land-use and environmental policy, amongst others. The mismatches between the different scales and levels at which these policies operate and those at which the problems are observed can hinder progress (Daniell & Barreteau, 2014). Polycentric governance, involving independent but interacting nodes of decision making at various levels, has the potential to help to address these mismatches between scales at which the problem arises and those at which it is managed (Ostrom, 2010; Walker et al., 2009).

Several institutional arrangements have been found to be effective at managing nutrient loading in agricultural watersheds, characterised by multiple dispersed and unequal upstream nutrient sources, lakes affected by eutrophication, and downstream users of recreational and other ecosystem services. Engagement between water and agricultural policy areas, as well as other relevant areas such as industrial and urban pollution control, is required to identify and ideally remove perverse subsidies (Moss, 2007). Strong vertical integration between the local-level authorities that can more effectively target measures and the higher levels of government that set the rules is helpful (Folke et al., 2004; Walker et al., 2006; Wardropper, Chang, & Rissman, 2015). For example, watershed organisations can help to translate national or subnational policy requirements into watershed plans tailored to the specific context of the watershed and taking account of its variable source areas (Gross & Hagy, 2017).

Bridging organisations and coordinating individuals or organisations can help to connect institutions at the same level, such as municipalities, as well as between institutions working at different levels and scales (Daniell & Barreteau, 2014; Rathwell & Peterson, 2012). This can be particularly helpful when they have different priorities based on their spatial position in the watershed, such as agriculturally-focused upstream municipalities and recreation and tourism-focused downstream municipalities (Rathwell & Peterson, 2012). The coordination of activities between and across levels has also been found to be helpful in promoting social learning, building understanding of the system and ensuring feedback from implementation at lower levels to policy at higher levels (Berardo, Turner, & Rice, 2019).

Regulations that allow flexibility in how farmers meet clearly-defined targets for water quality can enable innovation and experimentation with new approaches, as well avoiding costly changes to top-down legislation for farmers and enforcing regulators alike (Belinskij, Iho, Paloniitty, & Soininen, 2019). For example, results-based payments for agri-environmental measures are gaining increased attention as an alternative approach to incentivising farmers to take effective action. A study that compared conventional subsidies with results-based payments for measures to reduce nutrient loading to Chesapeake Bay found that the latter produced the same reductions in nutrients for half the cost of the former (Talberth, Selman, Walker, & Gray, 2015). Schemes such as the Florida Everglades Agricultural Privilege Tax, which is calculated according to water quality, avoid problems with accurately assessing the results achieved at farm level and identifying sources of phosphorus in a watershed. This is difficult due to the effects of legacy phosphorus from past land uses and internal loading from lake sediments. However, they rely on reliable monitoring of farm discharges, which may or may not be possible, depending on the configuration of agricultural drainage networks (McDowell et al., 2016).

2.3.3 Social Learning and Participation

Bottom-up participatory governance approaches have been found to be effective at delivering water quality improvements and restoration of lake ecosystems (Gross & Hagy, 2017), as well as participation in such decision making being a democratic right (Reed, 2008). The previously mentioned 4R certification programme in the western Lake Erie Basin is a good example of the effectiveness of participatory approaches in increasing farmer uptake of BMPs. The scheme was developed by a broad stakeholder body, giving it credibility and ensuring its implementation was practical (Vollmer-Sanders et al., 2016). Such schemes help farmers agree that there is a problem, understand their contributions, be supported in implementation and collaborate to ensure sufficient coverage of BMPs.

In these participatory processes, social learning is a key benefit. It can be defined as ‘learning together to manage together’ and therefore has an important role in improving management of complex and uncertain social-ecological systems (Pahl-Wostl et al., 2007). It enables stakeholders to contribute diverse experiences and knowledge bases to deepen collective understandings of the system, as well as raising their awareness of the issue of nutrient loading and their role in managing it (Olsson et al., 2004). The increased knowledge of the system encourages farmers to engage with nutrient management efforts, make appropriate decisions about BMPs and to build and share their understanding through implementation (Akkari & Bryant, 2017). For example, a research team studying nitrate pollution in several communes in Italy took a participatory approach based on social learning after their failure to integrate previous research results into the region’s Rural Development Plan. The shift in approach entailed participatory methods with stakeholders to understand nitrate pollution as the consequence of interactions between ecological and social factors and opened up dialogue about potential actions to address the problem (Toderi, Powell, Seddaiu, Roggero, & Gibbon, 2007). Social learning can also enable farmers to be prepared to react to a surprise in the system based on their own experiences and those of other individuals that have been shared through networks (Akkari & Bryant, 2017).

Social learning in agricultural watersheds through participatory approaches, networks and organisations need not be limited to farmers. Other stakeholders, particularly drinking water providers, recreational users of lakes and tourism and recreational businesses, also benefit from enhancing their knowledge of the system and have important knowledge to contribute. For example, a better understanding of the value of clear-water lake ecosystems, in terms of the ecosystem services they provide, can allow policy options such as payment for ecosystem services programmes to be considered. The beneficiaries of the clean drinking water and opportunities for recreation, amongst others, then can provide the funding for BMP implementation and the required research, advisory services and infrastructure (Farley, Filho, Alvez, & de Freitas, 2012). Management responses based on social learning processes therefore seek to expand beyond the actions of single actors addressing a single problem, to consider multiple actors managing the issues in the system across a range of scales (Olsson et al., 2004).

2.3.4 Adaptive Management

Linked to the need to enhance social learning is the need to transition to forms of adaptive management (Olsson et al., 2004). The social-ecological system in which nutrient loading of lakes takes place is complex, with interconnected ecosystems, ecological processes occurring at different scales, and characterised by considerable uncertainty. Adaptive management provides the opportunity to learn from policy and management interventions and then adjust based on new information and understandings (Medema, Mcintosh, & Jeffrey, 2008). In this case, adaptive management approaches can be used at the scale of BMPs to enhance the efficiency of phosphorus reduction. For example, constructed wetlands treating wastewater from the city of Orlando have been effective over the last 30 years, although winter peaks in phosphorus concentration in their effluent have been observed. An adaptive management approach allows different maintenance methods to be tested according to their impact on phosphorus removal efficiency (White, Sees, & Jerauld, 2018). Climate change may change the effectiveness of current BMPs for reducing nutrient loading, and this varies between watersheds. Large changes in the magnitude of spring snow melt and of the proportion of overland run off may render current BMPs less effective. Therefore, site-specific evaluation of BMPs will need to take into account climate change, and adaptive management can guide the approaches to be refined as understanding of the evolving climate improves (Crossman et al., 2016).

Effective management of nutrient loading in agricultural watersheds also happens beyond the farm boundary. For example, coastal wetlands around the Great Lakes play an important role in removing N and P from agricultural runoff before it reaches the lakes. However, these wetlands are also a source of concern due to invasions by *Typha* spp., which reduces biodiversity and habitat quality. On the other hand, such species have a rapid rate of N and P uptake; a recent study estimated that more than 10,000 tonnes of nitrogen and 1000 tonnes of phosphorus are stored in the biomass of *Typha* and two other invasive wetland plan species in the coastal wetlands of the Great Lakes. Therefore, mechanically removing such species could serve to both improve habitat quality and remove legacy nutrients in the coastal soils. An experimental harvest in a *Typha* dominated wetland on the coast of Lake Huron was assessed to determine that legacy phosphorus in the wetland could be removed in as little as ten harvests (Carson et al., 2018). Combining these off-farm methods with on-farm BMP implementation in a more coherent approach to managing the watershed enhances the effectiveness of single measures.

2.3.5 Transformation

If (external and/or internal) nutrient loading continues to lake ecosystems, they may undergo a regime shift to a turbid, eutrophic state. In this state, lake ecosystems can be resistant to change (Pihl et al., 2005). For example, cyanobacterial blooms can be resilient to reductions in nitrogen and phosphorus concentrations in water, and therefore can be little affected by efforts to reduce nutrient inputs (Aubriot & Bonilla, 2018). In particular, shallow lakes with short fetches and low flushing rates are more likely to resist recovery to a non-turbid state (May et al., 2019). In many lakes, internal loading continues as phosphorus is released from sediments and decomposing organic matter (Hupfer & Lewandowski, 2008). Furthermore, the resulting turbidity prevents macrophyte growth, and the lack of macrophytes then sustains the turbidity (Scheffer et al., 2000; Søndergaard et al., 2007). The resilience of the existing agricultural system may hinder further efforts to address the problem. In this case, the emphasis must be on the related concept of transformation (Walker et al., 2006).

To restore biodiversity and ecosystem services provided by the lake, a collective, sustained and multi-actor effort will be necessary to shift the lake ecosystem and the agricultural social-ecological system in which it is embedded to an alternative state. Several methods have been proposed to shift a lake ecosystem back to a clear state, including manipulation of lake species to enable filtering species such as charophytes to establish (Ibelings et al., 2007) and allowing a more natural variation in water levels in regulated lakes to allow shoreline vegetation to regenerate (Coops & Hosper, 2002).

Transformation of the agricultural system may involve a change in approach to managing nutrient loading, for example providing additional targeted support or incentivisation for BMP implementation. For larger scale schemes, trading schemes may be necessary to achieve an optimal spatial distribution of production (McDowell et al., 2016). These are based on a regulatory cap to limit the total nutrient export, alongside voluntarily tradeable permits or allowances. To account for the spatial variation in nutrient transport to waterbodies, location-specific trading ratios can be added. If well-designed and accompanied by farm extension services and transparency in assessments, such schemes can promote innovation (Deane & Hamman, 2017). Regardless of the combination of regulation, incentives, trading, etc., the aim should be to ensure that critical source areas are only occupied by farms that produce only very low levels of nutrients. More fundamental changes, such as to land tenure, may also be necessary to encourage the long-term farm planning that makes investing in BMPs financially worthwhile. In cases where nutrient loading persists despite policy and management efforts, removal of particularly critical source areas from agricultural production may need to be considered (McDowell et al., 2016).

3 Conclusion

The causes of nutrient pollution to agriculture are relatively straightforward but are challenging to address and manage for a variety of reasons, including the diverse number of farmers in a watershed, land tenure patterns, and variations in farming practices and local environmental, social and economic conditions. The consequences of nutrient pollution, in the form of turbid, eutrophic lakes, are difficult to reverse and they reduce the provision of valued ecosystem services such as recreation, drinking water and others. Conventional approaches to addressing these problems focus on tackling nutrient transport at a technical level on single farms. These have generally been insufficient in addressing the problem. Resilience-centred approaches offer the potential to improve participation, enhance adaptation to changing conditions, and increase shared understandings of the social and ecological dynamics that limit collective action.

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Reconfiguring Water Governance for Resilient Social-Ecological Systems in South America

Micaela Trimble, Pedro R. Jacobi, Tomás Olivier, Miguel Pascual, Cristina Zurbriggen, Lydia Garrido, and Néstor Mazzeo

Abstract The Global South is usually underrepresented in comparative water governance studies. Latin America has abundant water resources but is the most unequal region in terms of access to water. Water governance in Argentina, Brazil and Uruguay has been gradually moving from a conventional-centralized mode towards a decentralized, participatory and potentially adaptive approach. The purpose of this chapter is to analyze the main institutional changes in water governance during the past few decades in these three neighbouring South American countries, and how these changes have generated attributes which confer resilience to watersheds as

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social-ecological systems. A comparative case study approach was used to analyze the three countries, with document analysis as the key method. The findings show that the water governance reform started with changes or incorporations in the countries' constitutions (Brazil – 1988, Argentina – 1994, Uruguay – 2004). Another common trend is the government interest to adopt integrated water resources management (IWRM) principles, such as the river basin approach and the formation of river basin organizations, including participatory forums or boards involving government institutions, users and civil society. Brazil shows clear signs of polycentric governance, while polycentricity is more limited in Argentina and Uruguay, although there exists some enabling legislation.

1 Introduction

As chapter "The Emergence of Water Resilience: An Introduction" shows, water governance and water resilience are intimately related. The global Delphi study conducted by Plummer et al. (2014), identified attributes of aquatic system governance which indicate specified and/or general resilience, as well as themes of activities that enhance the governance capability of a system with low resilience. Some of the former attributes (which are relevant for the present chapter) are participant diversity and equity, inclusive participation, polycentric governance with boundary organizations, decentralized governance, adaptability, flexibility of planning processes, and institutional flexibility. Moreover, the study showed that themes of activities that enhance governance include forums/opportunities for participation, planning processes and tools to deal with disturbances, and improved transparency and legitimacy of decision making/planning processes (Plummer et al., 2014).

Broadening participation and promoting polycentric governance systems are two of the seven principles of resilience thinking (Biggs, Schlüter, & Schoon, 2015) and constitute important components of adaptive governance (Dietz, Ostrom, & Stern, 2003; Folke, Hahn, Olsson, & Norberg, 2005). This governance approach, increasingly advocated for water, includes the combination of different knowledge systems, adaptive management practices via iterative cycles of learning by doing, flexible institutions (rules in use) and multilevel governance systems, with capacity to deal with external perturbations, uncertainty and surprise (Folke et al., 2005). The interest in stakeholder participation in environmental management has increased significantly in the last decades, as well as the academic literature in the field (e.g. Luyet, Schlaepfer, Parlange, & Buttler, 2012; Paavola & Hubacek, 2013; Stringer et al., 2006). A systematic review of the new field of comparative water governance studies shows that "participation and stakeholder involvement" is a key component of water governance, although there is significant variety in the issues that are investigated in relation to participation (Özerol et al., 2018). One of the future research topics suggested by this review is to conduct longitudinal comparisons of water governance to identify temporal governance trends and patterns (Özerol et al., 2018).

Polycentricity has also been receiving a rapid expansion of academic interest (Thiel, Blomquist, & Garrick, 2019). Polycentric governance systems imply the existence of multiple centres of decision making, nested at multiple jurisdictional levels (e.g. local, state, national). Each centre operates with some degree of autonomy, acting in ways that take into consideration the actions and decisions of other decision-making bodies (Carlisle & Gruby, 2019; Ostrom, 2005; Ostrom, Tiebout, & Warren, 1961). A governance system like this "can be defined as a complex, modular system where differently-sized governance units with diverse purposes, organization, and spatial locations interact to form together a largely self-organized governance regime" (Pahl-Wostl, 2015, p. 113). Depending on multiple factors, polycentric governance arrangements perform well, persist for long periods, and adapt (Thiel et al., 2019). The interaction across organizational levels can foster learning and increase the diversity of response options, allowing the system to have higher flexibility and ability to adapt to unexpected changes. The capability to produce institutions that are a good fit for natural resource systems (i.e. institutional fit) is another advantage of polycentric systems frequently cited by commons scholars (Carlisle & Gruby, 2019; Lebel et al., 2006). In the case of water governance, there is empirical evidence that polycentric regimes, with distribution of power but effective coordination structures, have a higher performance in achieving water-related goals, and they are also associated with a higher ability to respond to challenges from climate change (Pahl-Wostl, Lebel, Knieper, & Nikitina, 2012). The potential pitfalls of polycentricity include transaction costs associated with coordination and dispersion of responsibilities (Carlisle & Gruby, 2019; Huitema et al., 2009).

The Global South is usually underrepresented in comparative water governance studies, where more research is needed (Mancilla García & Bodin, 2019a; Özerol et al., 2018). The Latin American region has 33% of global water resources, but faces severe difficulties, such as those related to water availability in some areas, water access, sanitation, etc. It is the most urbanized region and the most unequal in terms of access to water (see Poupeau et al., 2018). Over the last two decades, increasing attention has been given to social struggles in Latin America against the privatization of water services. For instance, Harris and Roa-García (2013) analyze "recent waves of water governance reforms" – constitutional changes that highlight a right to water and efforts to ban private water provision in several countries in the region (e.g. Uruguay, Ecuador, Bolivia). In Mexico, social movements grew during the 1990s (as part of a broader political aperture reshaping water governance), mobilizing against privatization and large-scale hydroelectric dams, among others (Wilder, 2010).

Water management in Latin America, like the global trend, has historically followed a technocratic approach based on the prediction and control paradigm, trying to control single variables. This command-and-control approach, still prevailing to some extent, has led to numerous negative implications, giving rise to alternative paradigms, such as integrated water resource management (IWRM), whose pillars include the integration across sectors, different uses and users; the incorporation of economic, social and environmental dimensions of sustainability; and the participation of multiple actors. In Latin America, this approach emerged partly due to its promotion by international organizations aiming to overcome excessive fragmentation in water management (e.g. Berardo, Meyer, & Olivier, 2013). Introducing participatory governance structures and promoting a holistic vision of water considering different interests were among the IWRM principles guiding governance changes in the region (e.g. Hordijk, Miranda Sara, & Sutherland, 2014; Mancilla García & Bodin, 2019b; Wilder, 2010).

In Argentina, Brazil and Uruguay, three neighbouring countries, water governance has been gradually moving from a conventional-centralized mode towards a decentralized, participatory and potentially adaptive approach, although at different paces. The purpose of this chapter is to analyze the main institutional changes in water governance during the past few decades in the three countries, and how these changes have generated attributes (such as polycentric arrangements and forums for participation) which confer resilience to watersheds as social-ecological systems. The challenges that the three countries are facing associated to their water governance reform are discussed.

2 Methods

We used a comparative case study approach to analyze the main institutional changes in water governance during the past few decades in Argentina, Brazil, and Uruguay. Although the three countries differ in size and allocation of freshwater resources, they all face similar problems regarding increasing inequality, pollution and water quality issues caused by an expanding agricultural frontier, all while dealing with challenges in the enforcement of water-related legislation. The three countries, for instance, share (along with Bolivia and Paraguay) one of the five largest drainage basins in the world – the Rio de la Plata Basin (del Castillo Laborde, 2008). Variations in policy preferences have led to confrontations between some of these countries regarding transboundary waters (Berardo & Gerlak, 2012). Despite sharing common water problems and a similar political culture, these countries differ in their governmental structures at the national level: Brazil and Argentina are federal countries, whereas Uruguay is unitary (Table 1).

The method we used for analyzing the cases was document analysis. We analyzed key legislation, policies, and literature (including previous research by the

Table 1 Main features of the three country cases

	(1) Brazil	(2) Argentina	(3) Uruguay
Surface	8.5 million km^2	2.7 million km^2	176,215 km^2
Population	210 million	40.1 million	3.4 million
Form of government	Federal (26 states + federal district)	Federal (23 provinces + City of Buenos Aires)	Unitary (19 departments)
Water governance reform start date	1988 (Constitution)	1994 (Constitutional reform)	2004 (Constitutional reform)

authors) regarding water governance in the three countries, identifying the key changes in legislation that have taken place in the last decades. To identify the key documents of study (and to analyze them), we focused on two of the attributes which were proposed to confer resilience to watersheds as social-ecological systems: polycentricity[1] and participation of diverse actors. This translated in searches for documents that defined and/or described the formal structure of decision-making regarding water governance issues at the national and subnational level in each country. All secondary data was analyzed from March to October 2019.

3 Water Governance Under Transition: Three Country Cases

This section analyzes the water governance reforms or shifts in the three countries (Brazil, Argentina and Uruguay), in decreasing order of area and of time lapse since the first important institutional (constitutional) change. Table 2 summarizes the main national policies focused on water in each country, and the challenges of implementation (or additional governance difficulties). Fig. 1 presents the main boards or forums for water governance, at national, subnational and local levels, in Brazil, Argentina and Uruguay.

3.1 Brazil: Polycentric Water Governance

Brazil is a country of continental proportions covering a vast area of around 8.5 million km^2, with a population of almost 210 million inhabitants. It is a Federal Republic composed of 26 states, a Federal District and 5570 municipalities, with the powers of government divided into three branches (executive, legislative and judicial), organized according to the principle of autonomy between the Union, or central government, the states and the municipalities. An important water governance challenge in Brazil is linked to demand management regarding possible increase, water supply in hydrographic regions with low availability, and water quality improvement with the reduction of domestic and industrial pollution. However, the access to sanitary services, especially in basic sanitation, is still an unresolved problem with serious environmental impacts in all country regions. Only 66% of households have access to sewage, and 73% of the sewage collected is treated.

Back in the 1960s, severe problems of water resource degradation became evident in some regions of the country, notably in metropolitan areas (Jacobi, 2004).

[1] We opted to use the polycentric concept since it was among the findings of the global Delphi study which identified attributes of aquatic system governance indicating specified and/or general resilience (Plummer et al., 2014). We recognize, however, that polycentricity is related to other concepts such as multilevel governance and network governance.

Table 2 Main national policies focused on water in Brazil, Argentina and Uruguay: highlights and challenges (the numbering of the highlights corresponds to that of the policies)

	(1) Brazil	(2) Argentina	(3) Uruguay
Policies	1.1. Federal Constitution – 1988 1.2. National Water Law (N° 9.433) – 1997 1.3. National Water Agency (N°9.984) – 2000 1.4. Water Resources National Plan – 2006	2.1. Constitutional reform – 1994 2.2. Law on Environmental Management of Water (N° 25.688) – 2002 2.2.1. National Water Resources Plan 2.3. General Law for the Environment (N° 25.675) – 2002 2.4 Guiding Principles for Water Policy – 2003	3.1. Constitutional reform – 2004 3.2. National Water Policy (Law N° 18.610) – 2009 3.3. National Water Plan (Decree 205/017) – 2017
Highlights	1.1. Proposes the creation of the National System for Water Resources Management. 1.2. Water Resources National Policy. Establishes the creation of the National System for Water Resources Management (SINGREH). Water basins are considered the territorial unit for policies planning and implementation. Encourages the rational use of water. Mandates participatory and decentralized management. Creates the National Water Council, the State Councils and Water Basin Committees. 1.3. ANA coordinates the implementation of the Water Resources National Policy and the National Information System on Water Resources. 1.4. Definition of policy guidelines oriented to improve water quality and quantity. Water is considered as a structuring element for the implementation of sectoral policies.	2.1. Federal government is responsible for establishing minimal standards of environmental protection (Art. 41). Provinces have original dominion over natural resources in their territory (Art. 124). 2.2. Minimal standards for water use and conservation. Basins are the basic units for water management. Creates basin committees in interjurisdictional basins, and the Federal Water Council. Mandates the creation of a National Water Resources Plan. 2.2.1 Framework for improving access to clean water, sanitation, economic development, water conservation, and flood protection. 2.3. Minimal standards for environmental protection and conservation. 2.4. Refines overarching principles for water policy, recognizing the social, economic, and environmental importance of water management.	3.1. Establishes access to potable water and sanitation as fundamental human rights; State provision of water for human consumption and sanitation services; citizen participation in planning, management and control; water basins as management units (Art. 47). 3.2. Reaffirmed all the elements of the constitutional reform. Integrated water management must consider environmental, economic and social aspects. Creation of multistakeholder participatory boards at national, regional (subnational) and local scales. 3.3. Overarching framework consisting of programs and projects to accomplish three objectives: water for human use, water for sustainable development, and risk management.

Challenges	1.a. Regional diversity in the implementation of Water Plans. 1.b. Conditionalities for effective action of Water Basin Committees. Actors' conflicting views of processes and goals. 1.c. Concentration of power in State governments and lack of transparency. Limitations to participation of representatives of civil society. 1.d. Discontinuity of policies and/or delay in implementation. 1.e. Weak inclusion of climate change adaptation in plans and policies.	2.a. Lack of a national water law. Variation in implementation of water principles at the subnational level, such as social participation. 2.b. Wide variation in authority assigned to regional instances (Basin Committees), especially within provinces. 2.c. Lack of formal involvement from local governments, technical groups and users. 2.d. Vulnerable economy subject to external shocks. Short-term policy planning. Lack of policy continuity. 2.e. Prevalence of *personalismo* (a small number of powerful individuals drive decision-making).	3.a. Fragmented competencies. Barriers to intra-institutional (e.g. within MVOTMA) and inter-institutional coordination/collaboration (e.g. MVOTMA-MGAP), to overcome centralized management. 3.b. Lack of integrated view of watersheds by government institutions (e.g. under-consideration of environmental and socio-economic aspects). 3.c. Limitations of basin commissions as multistakeholder participatory boards.

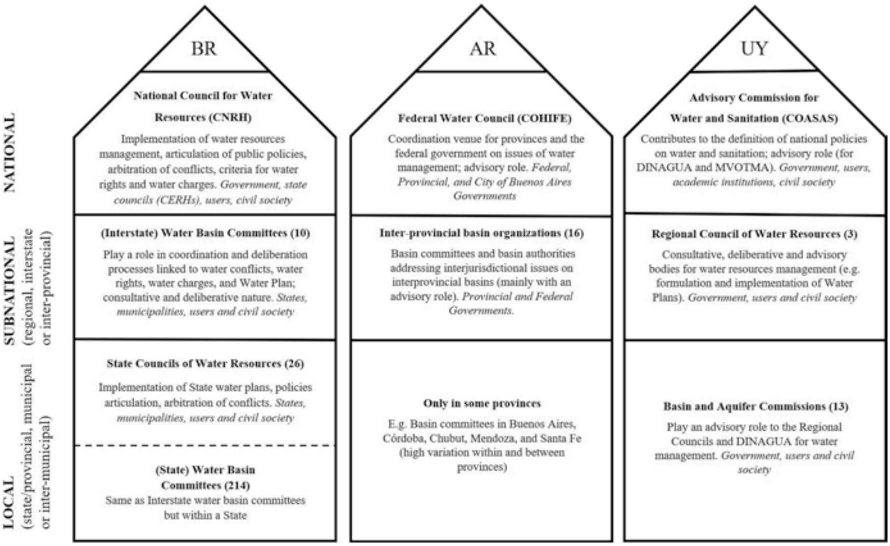

Fig. 1 Main boards for water governance in Brazil, Argentina and Uruguay, at different levels

Several factors were then responsible for the gradual shift in perspective on the ways of dealing with water resources appropriation and management. The increase in diversity and intensity of demands related to water resources indicated that their own physical characteristics required a more regionalized management approach. In the 1980s, the increased degradation process of water resources in areas of large urban-industrial concentration led to several mobilizations by social movements led by NGOs, such as SOS Mata Atlantica and Instituto Socioambiental, which played a role in favor of the recovery of water sources. It was then that a series of discussion forums were created, involving different actors. It was decided that there was a need for the creation of a national system of water resources, considering multiple water uses, the adoption of references for regional management, a decentralized participatory management, and a national water resources information system (Pagnoccheschi, 2003).

These recommendations were considered in the 1988 Constitution (the first post authoritarian regime), which included the proposal for a National System for Water Resources Management (SINGREH – Sistema Nacional de Gestâo de Recursos Hídricos). This process contributed to the promulgation of the Water Law in 1997 (Law 9.433). This law, despite referring to water resources, has a wider scope, since it recognizes water basins as the territorial units for the planning and implementation of policies (thus indirectly including land-use management). This law created the Water Resources National Policy and established the creation of the SINGREH (Barth, 2002; Jacobi, 2004; Pagnoccheschi, 2003). The System is constituted by the National Council for Water Resources (CNRH – Conselho Nacional de Recursos Hídricos), the Water Resources Councils of the States (CERHs – Conselhos Estaduais de Recursos Hídricos) and the Federal District (26 in total), Water Basin

Committees (CBHs – Comitês de Bacias Hidrográficas) and Consortiums, Water Agencies, and organizations of the public, federal, state and municipal powers whose competencies are related to water resources management (e.g. Barth, 2002; Brasil, 1997; Kettelhut et al., 1999). The SINGREH has the attributions of coordinating the integrated management of water resources; managing conflicts related to water use; implementing the Water Resources National Policies; planning, regulating and controlling use, preservation and recovery of water resources; in addition to charging for the use of water resources. The law institutionalizes five instruments for water resources management: (i) the Water Resources Plans; (ii) the categorization of water bodies in classes, according to predominant water uses; (iii) the licensing for rights of use; (iv) the charging of fees for use; and (v) the information system (Barth, 2002; Brasil, 1997; Tucci, 2004).

Participatory and decentralized management is a central principle of the National Water law, providing opportunities to users and the organized civil society for the participation in decision-making processes on the part of users and communities. The Water Basin Committees and Consortia have a role in coordination and deliberation processes, and they constitute innovative and privileged spaces for decision making, characterized by natural territoriality (the water basin) and they are composed by delegates representing State government, water users and civil society (Jacobi, 2004). There exist 214 state water basin committees (Agência Nacional de Águas [ANA], 2018) and ten federal or interstate committees (where more than two states have a river running through). State water basin committees depend on Water Councils of States, whereas Interstate committees depend on the National Water Council.

Each water basin committee has its own statute, where rules and procedures are defined related to performing deliberative assemblies, ways of participation, election and competences. This composition should reflect the representation of the sectors of public agencies (federal, state and municipal), water users and the water basin community. They may act through deliberation in various issues linked to water conflicts, basin plan, water rights, water charges, and also in a proactive way mainly to monitor the execution of the basin Water Plan, propose areas of the basin with restricted use, and issues linked to use of revenues from water charges. As to their consultative nature, they may promote debates and articulate the dynamics of the participating organizations. An important challenge many committees have faced is that the various actors involved in territorial dynamics have conflicting views and interests related to water use, processes and goals, hindering the search for solutions that are seemingly more egalitarian. All Brazilian states have a water resources council (CERH) or an equivalent entity. These collegiate bodies are mostly composed of representatives of public authorities, water users and civil society. Their duties include deliberating and monitoring the execution of the state water resources plan; promoting the articulation of sectoral policies related to water; arbitrating conflicts over state water use; among others.

In 2000, the National Water Agency (ANA – Agência Nacional de Águas) was created as part of the regulatory code necessary to promote the development of the SINGREH. ANA is an autarchy with special status, with financial and administrative autonomy. The Water Agency was partially created to accelerate the effective introduction of water resource management in the country, once the implementation of Law 9.433/97 was hindered and postponed due to the slow pace of the regulatory process of most of its instruments (Conejo, 2000; Kettelhut et al., 1999). It is up to ANA the role of implementing the Water Resources National Policy and the National Information System on Water Resources.

As mandated by Law 9.433/1997, the Water Plans are drawn up at three levels: river basin, state and national, and their preparation require the involvement of government agencies, civil society, users and various institutions. The Water Resources National Plan (PNRH – Plano Nacional de Recursos Hídricos) was approved in the CNRH in 2006, with the goal of guiding water resources decisions by the SINGREH. ANA (2018) data shows that 164 Water Plans were developed in 17 States of the Federation, and 32 are in process in ten States. These plans are coordinated and supervised by the water basin committees. At the water basin level these plans must be updated normally every 4 years, but they have not always been successful in keeping an agenda. Issues of adaptation to climate change are still very weakly approached in plans and policies.

Brazil water governance is polycentric, and the decentralization logic is based in the existence of boards and arenas that join state and municipal entities as well as civil society, aiming at a decentralized, participatory and integrated management system. The legislation incorporates, on national levels, the idea that the water issue is no longer a technical issue, external to society and exclusively subordinated to expert competence, suggesting instead a decision-making process open to different social actors who are dependent on its use, within a more pervasive revision of State attributions, the role of users and own water usage (Guivant & Jacobi, 2003).

The advances in both shared and participatory management have been quite relevant, defining a new logic of hydro-social management in the country, mainly on participatory aspects that strengthen the capacity of society to demand improvements in water quantity and quality as well as the questioning of inadequate water policies that affect human consumption and health. There are governance differences of water basin committees among the States. Although there is a normative paradigm, implementation of policies is defined in each State according to political agendas and problems linked to water stress and other types of conditionalities. Another challenge to be considered is that government changes at the national level also imply changes in the functioning of the National Water Agency facing the States.

3.2 Argentina: Polycentricity Meets Federal Boundaries

With a continental surface of 2.7 million km^2, Argentina possesses a wide variety of climates and altitudes. Although a water-rich country, surface water is unevenly distributed across the territory. Over 75% of the territory is in arid or semi-arid environments, with large areas where natural water availability levels are at or below water stress levels, as defined by United Nations standards[2] (Subsecretaría de Recursos Hídricos de la Nación [SSRH], 2017). Argentina has a mostly-urban population of 40.1 million (Instituto Nacional de Estadísticas y Censos [INDEC], 2010). The uneven distribution of water resources, a mostly-urban population, and the leading importance of the agro-industrial complex based on rainfed agriculture make Argentina susceptible to climatic extremes (Barros et al., 2015). In the last decades, Argentina has suffered from urban and rural flooding, causing economic losses of up to 1.1% of the country's GDP (SSRH, 2017), while the northeastern region has been significantly affected by droughts (Kuppel, Houspanossian, Nosetto, & Jobbágy, 2015; Pochat, Natenzon, & Murgida, 2006).

Argentina is organized as a Federal Republic, composed of 23 provinces plus the Autonomous City of Buenos Aires (seat of the Federal Government), and 2284 local governments (INDEC, 2016). The 1994 reform to the Argentine Constitution granted subnational governments (provinces) ownership and management of natural resources, including surface water and groundwater (Art. 124). Although the Federal Government does not decide on water management issues, the Constitution (Art. 41) trusts it with the protection of the environment and the ability to set standards for its use and conservation. The main water agency at the federal level is the Infrastructure and Water Policy Secretariat, dependent of the Ministry of the Interior, Public Works, and Housing. Other federal dependencies also influence water management decisions, such as the ministries of the Environment and Sustainable Development (regarding sustainable water use), Agro-Industry (regarding water for irrigation), and Foreign Affairs and Worship (regarding international basins).

Argentina does not have a "water law" *per se*, partially because the provinces are in charge of water management. Instead, water guidelines are present throughout multiple laws and codes. In Argentina, water governance reform began in 2002, when two federal laws pertaining to water were sanctioned (the "Environmental Water Management Regime" – Law 25.688; and the "General Law of the Environment" – Law 25.675). The Environmental Water Management Regime recognizes the watershed as an indivisible unit of environmental management, establishes minimum environmental protection requirements to preserve water, ensuring its sustainable use, and mandates the creation of basin committees for inter-jurisdictional watersheds to foster collaboration (Art. 4). The provinces challenged the law for considering it an act of federal encroachment. In response to this legislation, multiple provincial and regional workshops were held throughout the country starting in 2003. The workshops resulted in the creation of 49 "Guiding Principles for Water Policy", defining "technical, social, economic, legal, institutional, and environmental aspects of water management" recognized by the provinces and the federal government. The principles were meant to facilitate a new, more

[2]According to the Food and Agriculture Organization of the United Nations, water stress conditions occur whenever renewable water resources within a region are at betweeen 500 and 1000 cubic meters per capita (Steduto, Hoogeveen, Winpenny, & Burke, 2017).

comprehensive water law, which has not been sanctioned yet. The principles did contribute to the creation of the Federal Water Council (Consejo Hídrico Federal – COHIFE), which is the only formal instance for water policy coordination at the federal level. Its members are the 23 provinces, the Autonomous City of Buenos Aires, and the Federal Government.

Argentinian provinces participate in basin organizations (committees and authorities) for dealing with water management issues in 16 inter-jurisdictional basins (users or non-governmental organizations participate in some basin organizations, but only in consultative roles). Some of these organizations have been active since 1976, such as the Committee of the Colorado River – COIRCO (of which Buenos Aires, La Pampa, Mendoza, Neuquén, and Río Negro are members). Since provinces own their water resources, each organization relies on the authority vested upon them by its members and depends on consensus among the parties to make joint decisions. The 16 interprovincial basin committees act mainly as venues for policy coordination among provinces (leaving implementation to each member province), although some organizations like the Limay, Neuquén, and Negro Rivers Interbasin Authority (Autoridad Interjurisdiccional de las Cuencas de los ríos Limay, Neuquén y Negro – AIC) and COIRCO have authority over dam management, and monitoring the implementation of hydropower licenses.

Consensus-based approaches for the governance of transboundary water face challenges when conflict emerges. In Argentina, the Supreme Court has acted as venue for deactivating conflict, with varying degrees of success. A paramount example of this is the Atuel River case, a river shared by the provinces of Mendoza and La Pampa. Mendoza's extensive use of the river has reduced the flow reaching La Pampa, affecting rural communities and their ecosystems (Langhoff, Geraldi, & Rosell, 2017; Rojas & Wagner, 2016). In 1987, the Supreme Court ruled that Mendoza should recognize the "inter-provincial" nature of Atuel. However, given the importance of the Atuel for Mendoza's economy, the lack of incentives to cooperate, and the need of consensus to address inter-jurisdictional water disagreements, the conflict is still unresolved. Another example is the Matanza-Riachuelo case. In 2008, the Supreme Court declared the Province of Buenos Aires, the City of Buenos Aires, and the Federal Government responsible for the pollution of the Matanza-Riachuelo basin. The Court mandated that the parties, through an inter-jurisdictional basin authority (the Matanza-Riachuelo Basin Authority – Autoridad de Cuenca Matanza-Riachuelo, ACUMAR) develop and implement a clean-up plan, under oversight of the Supreme Court, the Argentine ombudsman, environmental NGOs, and the public. Over 10 years after the ruling, ACUMAR has achieved important milestones towards cleaning portions of the river, but its main challenge remains establishing guidelines to guide the clean-up in the long term.

At the provincial level, there is wide variation in the design and implementation of institutional arrangements for dealing with water issues. For instance, not all provinces grant water resources the same recognition in their constitutions; Buenos

Aires, Corrientes, Chaco, Chubut, the City of Buenos Aires, and Santiago del Estero, explicitly mention mechanisms for user participation in decisions regarding water or environmental issues. Other constitutions (such as Misiones') do not mention the word "water" in their text. Provinces like Buenos Aires, Córdoba, Chubut, Mendoza, and Santa Fe have developed basin committees in their territories, with varying degrees of attributions and formalization (Instituto Nacional del Agua [INA], 2010; Pochat, 2005).

Water governance is not only affected by the design of multi-level governing arrangements. The context in which those policies and legislation are implemented matter. In a country where governors possess de-facto veto powers in federal policymaking (Ardanaz, Leiras, & Tommassi, 2014), such dynamics can in turn limit the passing of legislation that grants the federal government authority over the provinces on inter-jurisdictional issues such as water governance. In addition, other contextual variables, such as economic crises put institutions and dynamics to a test. In 2015, the federal government launched a new National Water Plan (Plan Nacional del Agua – PNA),[3] estimating an investment of U$S 40.000 million (SSRH, 2017). In 2018, misfortunate macroeconomic decisions along with changes in the global markets led to an economic crisis in Argentina (Nelson, 2018; Organization for Economic Co-operation and Development [OECD], 2018). The economic recession limited the access to external and private funding, jeopardizing the implementation of many of the Plan's projects.

In sum, Argentina's institutional landscape regarding water governance is inherently complex. Even though granting provinces the ownership of natural resources could in principle facilitate policy innovation, the ill-developed institutional landscape and governance practices conspire against such innovation. Largely, we argue, this is the result of the constitutional mandate of provincial ownership of natural resources, which in practice has reduced transboundary collaboration to the will of each province. In spite of this, Argentina has taken steps towards improving that institutional landscape, namely the sanctioning of law 25.688 and the Guiding Principles for Water Policy. The design and implementation of enhanced policies, however, has been piecemeal and highly variable among provinces, product of an institutional system that is poorly-articulated and fails to incentivize cooperation (Berardo et al., 2013; Defensoría del Pueblo de la Nación, 2018). The Supreme Court was able to incite collaborative approaches to the management of the Matanza-Riachuelo basin; yet it remains unlikely that major policy change will occur through the judicial route alone. The discontinuity in policy evolution due to recurrent economic crises and pork barrel politics (Berardo et al., 2013) pose additional hurdles for the development of polycentric and adaptive approaches to water governance.

[3] This plan is a continuation of a 2002 plan mandated by Law 25.688, focusing on access to water and sanitation, climate change adaptation, water for rural and industrial production, and integrated water management (through the development of new infrastructure) (SSRH, 2017).

3.3 Uruguay: Integrated Water Resource Management Paradigm

Uruguay is a small country (176,215 km^2) with around 3.4 million inhabitants. It is a unitary state, territorially decentralized in 19 departments (main subnational administrative units) and 112 municipalities (third tier of government, after the national and departmental levels). Continental aquatic resource management in the country has been experimenting a series of transformations associated to varied drivers of change. Concomitantly to several institutional changes (expanded below), land-use transformations, such as the expansion of agriculture and forestry areas and the reduction of livestock areas (maintaining and expanding the stock), have contributed to diverse problems of eutrophication and water quality (Mazzeo et al., 2015).

Participation in water management has an important legal landmark in Uruguay in 2004. At that time, there was a referendum in which the society voted to approve (64.7%) a Constitutional Reform (Article 47): to leave water supply under the responsibility of the State; to define access to potable water and sanitation as fundamental human rights; and to include the participation of civil society in planning, management and control of water resources, setting the basin as the basic unit. The referendum was promoted by the National Commission in Defense of Water and Life (CNDAV – Comisión Nacional de Defensa del Agua y de la Vida) which had been formed in 2002 by several civil society organizations and the trade union representing the employees of the state-owned water and sewerage company (OSE – Obras Sanitarias del Estado), after some State initiatives to privatize water supply (Santos, 2010; Zurbriggen, 2014). This constitutional reform laid the basis for a transition from a fragmented and technocratic approach towards a more integrated management model.

In 2005 the National Directorate of Water and Sanitation (DINASA, now DINAGUA – Dirección Nacional de Aguas) was created (Law 17.930) within the Ministry of Housing, Land Planning and Environment (MVOTMA – Ministerio de Vivienda, Ordenamiento Territorial y Medio Ambiente). This ministry is the highest water authority, in terms of water use, management and control, through DINAGUA and the National Directorate of the Environment (DINAMA – Dirección Nacional de Medio Ambiente). They tend to work separately: DINAGUA oversees water quantity and DINAMA supervises water quality. Additional ministries also have competencies related to water issues. The competencies of local governments (departments) include to act as "people's hygienic and sanitary police", and to design and manage rainwater.

Law 17.930 also determined the creation of the first inter-institutional and multi-stakeholder forum at the national level,[4] the Advisory Commission for Water and Sanitation (COASAS – Comisión Asesora de Agua y Saneamiento), with the aim of

[4]At the local level, multistakeholder and advisory "Irrigation boards" (*Juntas de riego*) were created by the Law 16.858 (1997). In 2016, there were 17 in the country (Deci Agua, 2016a).

"incorporating different visions to the policies of the sector". The participatory and integrated dimensions of water management were further developed in 2009 with the National Water Policy (Law 18610), whose preparation had important contributions from COASAS. This law reaffirmed the principles of the constitutional reform and institutionalized a "sustainable, integrated and participatory management" of water. The law recognizes the "hydrographic basin" or watershed as the "unit for action" for planning, control and management of water resources, in decentralization, land planning and sustainable management policies (Art.8).

Also, the National Water Policy establishes that users and civil society should participate in an effective and real manner in the formulation, implementation and evaluation of plans and policies (Art.19). In particular, the law determined the creation of three types of multistakeholder boards, at national, regional (subnational) and basin scales, each with a tripartite and equitable composition, with members of the government (national and subnational), users (public and private) and civil society (social and non-governmental organizations, unions, teaching and academic institutions). The National Council for Water, Environment and Territory has not yet been formed. There exist three Regional Councils for Water Resources (covering the entire country) and 13 Basin and Aquifer Commissions (as of 2019). They are defined as consultative, deliberative and advisory bodies. MVOTMA oversees all these boards; DINAGUA presides them, although one of the basin commissions is led by DINAMA.

Several aspects of these multistakeholder commissions as participatory forums should be highlighted. Firstly, they constitute an arena for inter-institutional coordination between government organizations at different levels, and for interaction and learning between government and non-government actors. Secondly, there is a rich diversity of participating actors, suggesting their inclusive and plural nature; the composition varies among commissions, since this depends on the local actors of each territory, a sign of flexibility. Thirdly, the agenda of each commission is defined collectively, among the different parties, and decisions tend to be made through consensus building. Examples of accomplishments by these commissions include action plans and precautionary measures to protect water quality.

Nonetheless, drawbacks and challenges of basin commissions are numerous (e.g. Beder et al., 2013; Deliberación Ciudadana sobre el agua [Deci Agua], 2016b; Vida Silvestre Uruguay – PROYECTO ECCOSUR, 2018). Intra-institutional and inter-institutional coordination, between and within government levels, is still difficult and problematic at times. Even though the Regional Councils were formed as part of a decentralization strategy, fragmentation still prevails, as each organization tends to have its own "road map" and priorities. The challenge is also to overcome the administrative divisions to focus on the watershed or basin, with an integrated view of all its components.

The operation, coordination and progress of most commissions depend entirely on MVOTMA (although a few present leadership from local governments). Conflictual relationships are sometimes evident between the government and users or civil society organizations. The latter tend to complain about the operation of basin commissions, arguing that: only limited actions are taken; national agencies do not respond to some management proposals; participation is not binding; progress is generally slow; and the frequency of meetings tends to be low. DINAGUA's human resources for these participatory forums (Technical Secretariat) are indeed scarce, and although other institutions should assign human resources to this Secretariat, this has not happened yet.

A few years after the promulgation of the National Water Policy, several interinstitutional organizations were formed to contribute to a more integrated implementation of environmental public policies (although some argue that there are too many interinstitutional arenas for the same few government people, who become overloaded). For instance, the National Secretariat on Environment, Water and Climate Change (SNAACC – Secretaría Nacional de Ambiente, Agua y Cambio Climático) was created in 2015, under the Presidency of the Republic, to provide support and supervise the National Environmental Cabinet, composed of the country's President, the Chief of SNAACC, and members of six ministries. The SNAACC appears to be acting as a bridging organization, helping to improve the cooperation between government agencies at different levels, and among these and other actors. This secretariat has helped implement certain agreements arising at basin commissions, which involve more than one ministry or government level.

The SNAACC, together with MVOTMA, is in charge of ensuring the implementation of the National Water Plan (PNA – Plan Nacional de Aguas), which was approved in 2017 (Decree 205/017) after a public consultation process in 2016 which involved COASAS, Regional Councils, Basin Commissions, and a citizen panel, among others. The PNA has three main objectives: (i) to ensure the human right for potable water and sanitation, prioritizing social rationales over economic ones; (ii) to ensure water quantity and quality for the social-economic development of the country, biodiversity conservation and ecosystems' functioning, through integrated and participatory management; and (iii) to prevent, mitigate and adapt to the effects of extreme events and climate change, focusing on risk management (MVOTMA, 2017). Even though integrated water management is among the goals of this Plan, during its creation process (and consultation period) there was poor communication with a concomitant and closely-related process: a bill to modify the Irrigation Law, which was under discussion before the Parliament and had several controversial aspects. This is a sign of the still fragmented approach for policy design, and the somewhat unconnected actions of the Ministry of Environment and the Ministry of Livestock, Agriculture and Fisheries (MGAP – Ministerio de Ganadería, Agricultura y Pesca).

Both the National Water Policy (2009) and the PNA (2017) recognize the need for policy monitoring and evaluation (e.g. water plans at national, regional and local levels must be evaluated and revised periodically). The PNA establishes that its content will be revised entirely every 5 years, and its revision will include COASAS, Regional Councils and Basin Commissions (Art.6). Regional and Local Plans are currently being drafted. The fact that monitoring/evaluation is institutionalized and that management plans will be tailored to different scales (considering context-specific conditions) contribute to laying the basis for adaptable and flexible water governance. The materialization of these *de jure* conditions will need to be assessed.

4 Discussion

The three country cases analyzed in this chapter (Argentina, Brazil and Uruguay) show some general trends, which parallel the situation of other South American countries. First, a benchmark of the water governance transition appears to be in the countries' constitutions (Brazil – 1988) or reforms to their constitutions (Argentina – 1994, Uruguay – 2004), which were followed by national water laws (or law of environmental management of water in the case of Argentina) and national water plans. The analysis of these policies showed that the three countries possess enabling legislation for key governance attributes indicating resilience, such as polycentric governance, decentralized governance, forums for participation, and planning processes to deal with disturbances (Delphi study by Plummer et al., 2014).

Second, in these water governance reforms there was explicit intention to adopt IWRM principles, giving more attention to the ecological and social impacts of water management activities, and to the need for involving different sectors and government levels, working coordinately. As part of the IWRM approach, the "water basin as the key planning unit" was found in the legislation of the three countries, which generally appears to be a key innovation that the water governance community is after (Huitema & Meijerink, 2017). However, making changes in the legislation does not suffice, as shown in the number of implementation challenges summarized in Table 2, such as fragmented competencies, concentration of power in the central government, variations among provinces or states. Fragmented bureaucracies and rigid central coordination are usual challenges for polycentric governance (Pahl-Wostl, 2015). The relationship between the national and subnational governments is a key aspect. In unitary countries like Uruguay, the implementation of IWRM reforms will depend largely on the actions of the national government. Implementing these reforms in federal countries like Argentina and Brazil requires that the federal authorities negotiate with the members of the union. In Brazil, the federal government plays a central role by assuming some responsibilities in the management of inter-jurisdictional basins. In Argentina, the role of the federal government is more limited, which in part has resulted in the more piecemeal implementation of IWRM principles nationwide. Even though many countries worldwide have made changes in their legislation to include IWRM principles, it has been found that their implementation remains slow, and thus, IWRM has not led to profound changes (Pahl-Wostl, 2015; Rockström et al., 2014).

Third, as presented in Fig. 1, the three studied countries have adopted the formation of different kinds of river basin organizations (RBO), which is another sign of a shift in governance (Huitema & Meijerink, 2017). There are multiple types (and typologies) of RBO, with different sizes, shapes, roles and composition. Huitema and Meijerink (2017), distinguished between autonomous river basin organizations, agencies, coordinating basin organizations, and partnerships. Mancilla García and Bodin (2019b) claimed that basin forums (integrating government entities, private users, and civil society) are the type of institution on which the water governance literature has largely focused. They argued that the institutional histories, structures, aims and agendas of these basin forums depend greatly on the biophysical and socio-political context in which they are set (Mancilla García & Bodin, 2019b).

In many respects, Brazil appears to be the most advanced country (compared to Argentina and Uruguay) in terms of achieving IWRM and polycentric multilevel governance, where “decision making authority is distributed within a nested hierarchy and does not reside or is not concentrated at one single level” (Pahl-Wostl, 2015, p. 113). It may not be coincidence that Brazil is also the country which started the earliest with its governance reform, suggesting that time is an important variable, and that real shifts in governance modes may take decades (as claimed by Hordijk et al., 2014, who analyzed case studies from four cities in the Global South). Brazil is the only country of the three with a National System for Water Resources Management (proposed in their Constitution – late 1980s, implemented through the National Water Law – late 1990s), and the only one with a National Information System on Water Resources already implemented. It is also the country showing the largest trajectory and diversity of RBO, such as participatory boards for water governance at different scales (mandated by the National Water Law). For instance, there are 224 Water Basin Committees, deliberative arenas composed of members of the government, users and civil society, distributed among most of the country’s states. The participation of members of civil society (NGOs, social movements, community movements) in decision-making processes, together with private sector and representation of State and municipal governments, has been one of the most relevant advances within the transformation that has been taking place in the Brazilian legislation of water resources since the 1990s. However, the evaluation of participatory forums for water governance in the country has shown mixed results (see Mancilla García & Bodin, 2019a); sometimes the participation of civil society is poorly stimulated or has little influence in decision making.

In Uruguay (as in Brazil), society mobilizations had an important role for achieving legislative changes, such as those referring to the incorporation of citizen participation in planning, management and control (although there are social concerns about the little influence their input has on decision-making). After the national water policy, passed a decade ago (2009), Uruguay has shown an increase of interinstitutional cooperation and society participation, associated to the formation of basin commissions and other interinstitutional/multistakeholder forums (Mazzeo et al., 2019). However, the transition from command-and-control towards IWRM and polycentric adaptive governance faces multiple challenges. The fragmentation challenge is partly related to the prevailingly reductionist university education (Mazzeo et al., 2015), which hampers the incorporation of systemic and integrated approaches in decision-making and policy design processes (however, interdisciplinary university degrees have emerged over the years).

In the case of Argentina, water governance is poorly coordinated among provinces. At least formally, it is the least advanced of the three countries in terms of user and social participation in management. For instance, the Federal Water Council is an intergovernmental arena only, whereas its counterparts in Brazil and Uruguay do include representatives of users and civil society. Many provinces in

Argentina do not have formal and stable participatory forums to address water issues, such as basin committees with user participation (even though one of the "Guiding principles for water policy" claims society's participation in goal setting of water plans, decision-making processes and management control). Moreover, external drivers, such as economic crises and changes in administrations, have slowed down water governance reforms.

5 Conclusions

This chapter has contributed to the achievement of the first objective of the book, that is, to synthesize current knowledge and understanding of management and governance in the context of water resilience, in three South American countries (Brazil, Argentina and Uruguay). The three countries possess (although to different degrees) enabling legislation for key governance attributes indicating resilience, such as polycentric and decentralized governance, and forums for participation. This legislation (such as national water policies) have allowed for a shift in governance mode, inspired by IWRM principles, slowly leaving behind the prevailing command-and-control approach. An important sign of this shift in governance is the formation of different kinds of river basin organizations, such as basin committees involving government, users and civil society. Brazil appears to be the most advanced country of the three in terms of achieving IWRM and polycentric multilevel governance (its water reform started 30 years ago), whereas Argentina is the least advanced, particularly with regards to user and social participation in management.

The findings have shown that the transition from command-and-control to IWRM and polycentric governance carry numerous challenges, such as those associated with the concentration of power in the central government, interinstitutional cooperation within and across levels, and power sharing with non-governmental actors. In contexts of uncertainty and multiple kinds of water crises, forums for stakeholder participation at multiple scales constitute desirable tools for fostering resilience and adaptation. The three cases reviewed in this chapter provide examples of alternatives to achieving this participation.

Moreover, the studied country cases provide insight on how institutional factors, macroeconomic characteristics, policy design and implementation facilitate or hinder the transition of the governance system to a more participatory, polycentric and multi-level one, which is required for more resilient water systems. It is crucial that the countries incorporate monitoring and evaluation of ongoing institutional changes related to water governance in order to promote learning. Capacity building at different scales and levels is also needed to achieve polycentric and adaptive governance.

The use of a single method (document analysis) must be recognized as a limitation of this research, since policy documents often are not a full representation of what happens in practice. However, we addressed these de jure vs. de facto differences to some extent through the analysis of existing research and previous work of the authors.[5] Future research could assess (based on primary and secondary data) the performance of the new water policies in Argentina, Brazil and Uruguay, their associated outcomes and the governance implications. Furthermore, it could investigate how the basin committees perform, and identify the challenges posed by diverse contexts and institutional histories (Mancilla García & Bodin, 2019b), addressing the research gap of comparative studies in the Global South (Özerol et al., 2018).

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[5]Also, we are currently developing a comparative research project on adaptive and anticipatory water governance (GovernAgua) which involves the collection/analysis of primary (interviews, participant observation) and secondary data in six watersheds (two in each country – Argentina, Brazil and Uruguay).

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Part III
Exploring the Conceptual Boundaries and Bridges of Water Resilience

Capacities for Watershed Resilience: Persistence, Adaptation, and Transformation

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Abstract Water management and governance at the watershed scale is complex, with attention needed to the realities of fit with institutional arrangements and consideration of the dynamic and uncertain nature of social-ecological systems. The concept of social-ecological resilience and its application to water resources – 'water resilience' hereafter – offers a framework by which to approach these critical considerations. Water resilience is defined by three concepts: persistence; adaptation; and, transformation. These concepts are each complex themselves, and there has been little attention to the relationships among them. We describe the areas of overlap and uniqueness among these concepts through the identification of factors that underlie each. Then, we draw upon three case studies of watershed organizations to illustrate overlap and uniqueness. Through these conceptual exercises we identify substantive areas of overlap among persistence, adaptation, and transformation and that case studies exhibit factors related to all three concepts, even when the case is primarily focused on one. Overlapping factors of particular note include diversity and redundancy, connectedness, and learning. We also identify that, while factors may overlap among persistence, adaptation, and transformation, the underlying intent is different. Ultimately, we find that the boundaries among the concepts that comprise water resilience are fuzzy and depending upon the needs and/or

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desires of watershed organizations to persist, adapt, or transform, different factors and qualities of those factors that align with those intentions may be emphasized.

1 Introduction

Understanding of the hydrological cycle has long informed conceptualization and management of water resources. Integrated water resources management (IWRM), as introduced in the opening chapter of this volume, intensified in the 1990s and the derivative, Integrated River Basin Management (IRBM), is a mainstay for management that occurs based on hydrological boundaries and the direction of water drainage) (Huitema & Meijerink, 2017; Molle, 2009). IWRM and IRBM are not simply about organizing management according to a watershed boundary. Rather, they are about using a particular framework for analyzing challenges and making decisions that was intended to allow for consideration of the broader ecological system, and to some extent the social system as well. Despite these advances, the foundation upon which they are based (closed systems, predictability, stability) have eroded and an alternative perspective has emerged, "…which portrays river basins as unstable, open and chaotic socio-biophysical systems, giving rise to 'wicked' or 'messy' management problems characterized by complexity, change, uncertainty and conflict" (Watson, 2004, p. 245). Past notions of a stable system are no longer valid (Milly et al., 2008). A vast discussion is now underway on how water management and governance ought to occur in this context.

Attentiveness to the fit between institutional arrangements and ecosystems as well as linkages with users are paramount to social-ecological systems thinking in this context (e.g., Epstein et al., 2015; Folke, Pritchard, Berkes, Colding, & Svedin, 2007; Galaz, Olsson, Hahn, Folke, & Svedin, 2008; Lebel, Nikitina, Pahl-Wostl, & Knieper, 2013). de Loë, Armitage, Plummer, Davidson, and Moraru (2009) argue that "…a general consensus is emerging that environmental governance should involve forms of group decision making that accommodate diverse views, that networks and hybrid partnerships among state and non-state actors are needed, that shared learning is critical, and that governance should provide opportunities for adaptability and positive transformation" (p. iv). Huitema et al. (2009) note that these institutional prescriptions resonate with the insights (theoretical and conceptual) specific to the water governance literature of collaboration, public participation, an experimental approach, and the bioregional scale. Questions as to the benefits of the 'watershed approach' have arisen, with the debate focusing specifically on elements of participation and accountability (Cohen & Davidson, 2011). At the same time "…particular features of the watershed approach—namely, their physical size and the shared discursive framings they employ ('stakeholder' and 'integration') make the watershed concept both cohesive enough to travel among different epistemic communities, and plastic enough to be interpreted and used differently within them" (Cohen, 2012, p. 2207).

From a critical perspective, the current hegemonic status of multi-stakeholder platforms, integrated water resources management, and river basin management may be challenged as they are each matters of choice (see Warner, Wester, & Bolding, 2008). As Molle (2009) highlights, the focus on the watershed or river basin is framed in ways that claim the physical boundaries are a "natural" unit upon which to base governing institutions. Treating "natural" as if it is equivalent to "politically neutral", this concept has been used to rescale water governance (Norman & Bakker, 2009). The "natural" unit is based on a Western-science defined boundary system, and in that way, is rooted in Western knowledge systems and the rationality of science. The dominance of this science paradigm in water management and the focus it placed on the "hydraulic mission" has been widely acknowledged (Swatuk, 2008), but one outcome of its long history in watershed management is that the discourse of multi-stakeholder platforms, IWRM, and river basin management is that it tends to ignore Indigenous ways of knowing (Castleden, Hart, Cunsolo, Harper, & Martin, 2017; Jackson, Storrs, & Morrison, 2005) and the territorial borders that Indigenous nations have and continue to use (Blomquist & Schlager, 2005; Norman & Bakker, 2009; Warner et al., 2008). Moreover, the emphasis in the literature about watershed or river basin organizations has tended to treat Indigenous nations as "one of" many stakeholders who could have a seat at the "table", without acknowledging their rights, title, and autonomy (Baltutis & Moore, 2019; Castleden et al., 2017). This is true in numerous countries where this model has come to dominate.

The ways in which water is managed and governed must reflect the contemporary realities of fit between ecosystems and institutional arrangements as well as the dynamic and uncertain characteristics of complex adaptive systems (Baltutis & Moore, 2019). Water resilience, as an approach to management and governance, reflects these realities and is informed by three main concepts: persistence (the ability of a system to change by absorbing disturbances and reorganize while undergoing changes to retain essentially the same identity and set of functions), adaptability (the ability of actors to adjust actions to influence resilience), and transformability (the capability to become a different kind of system when the present system is untenable) (Folke, 2006; Folke et al., 2010; Folke, Biggs, Norström, Reyers, & Rockström, 2016; Walker & Salt, 2006). These three concepts are not entirely new for those concerned with water management and governance as entities have focused on watersheds for some time. However, there is a lack of understanding about the capacity of watershed-based organizations to navigate complex systems change (Moore & Baltutis, 2016).

These three concepts – persistence, adaptation, and transformation – are often used in concert regarding resilience (e.g., Chaffin, Craig, & Gosnell, 2014; Folke et al., 2016; Pelling, O'Brien, & Matyas, 2015), however, the relationships among them remain obscure (Fig. 1). There are several possible reasons for this: our understanding of concepts, and the broad relationships between them, has shifted over time; each of these concepts is complex, with a range of (potentially overlapping) factors that relate to disparate levels or arenas (e.g., individual vs system level factors); and, scholarship related to each concept varies in that some is more or less mature (e.g., in terms of conceptual and empirical study). Efforts to gain clarity and

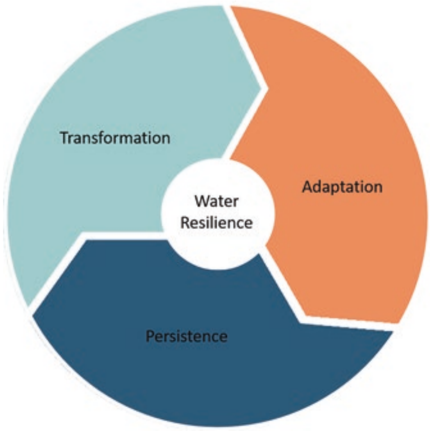

Fig. 1 Persistence, adaptation and transformation as the three key constructs that define water resilience

'make sense' of the relationships among factors for persistence, adaptive capacity, and transformative capacity are critical as we move forward in resilience assessments and draw on these key concepts to do so. In this chapter, we start by describing resilience before unpacking each of the concepts that inform it and subsequently identifying their underlying factors. In doing so, we describe the areas of overlap and uniqueness among these concepts. We draw on case studies of watershed organizations to illustrate the tensions that arise at the intersection of resilience capacities as well as highlight the unique factors associated with each. To this end, we provide the groundwork for re-orienting conceptual and applied practice for watershed organization resilience.

2 Resilience

How resilience is conceptualized and defined has evolved and branched into new areas over time (Quinlan, Berbés-Blázquez, Haider, & Peterson, 2016). Early on, the concept of ecological resilience was informed by Holling (1973) and in particular his research with colleagues who modelled insect outbreaks and demonstrated how sudden events such as spruce budworm outbreaks could trigger a shift between different regimes, e.g., from a forest filled with old trees and more budworms than birds are able to control, to a forest of young trees and relatively few spruce budworms (Gunderson, Allen, & Holling, 2010; Holling, 1986). This type of non-linear change and re-setting of internal system feedbacks (i.e., the effects of a change in one part of the system on other parts of it) had implications for how ecosystems were managed and drew attention to the uncertainty and unpredictability of complex adaptive systems. Importantly, this emerging understanding of system dynamics highlighted how management decisions based on the opposite assumptions of cause-effect linearity, certainty, and control risked eroding resilience and setting the system up for collapse (Holling & Meffe, 1996). The phenomenon of abrupt regime shifts is an enduring concept central to resilience theory that features in many different types of systems (Rocha, Yletyinen, Biggs, Blenckner, & Peterson, 2015; Scheffer, Carpenter, Foley, Folke, & Walker, 2001). As defined by Rocha et al. (2015), a regime is a "persistent organization of mutually reinforcing structures and processes. A regime shift occurs when a combination of stronger destabilizing feedbacks, weaker stabilizing feedback processes and external shocks cause the system to reorganize around a different set of mutually reinforcing structures and processes" (p. 1). More commonly systems change in slow or incremental ways. Focusing on the dynamics of change in systems, the adaptive cycle and Panarchy model of nested adaptive cycles, further contributed to the conceptualization of resilience of complex adaptive systems, where system structure, memory, legacies, and novelty, can interact across scales of time and space (Gunderson & Holling, 2002).

The initial discovery by Holling (1973) that ecological systems can shift among multiple states and have an inherent capacity to cope with disturbance, merged over time with the recognition that humans are part of the system, and that these social-ecological systems are comprised of many interacting parts that together give rise to how a system behaves (Folke, 2016). With its roots in natural resource management, resilience research began to engage more fully with human dimensions with the publication in 1998 of Berkes and Folke's book *Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience*. More recently, Biggs et al. (2012, 2015) identified seven generic principles for building social-ecological resilience that include: (1) maintain diversity and redundancy, (2) manage connectivity, (3) manage slow variables and feedbacks, (4) foster complex adaptive systems thinking, (5) encourage learning, (6) broaden participation, and (7) promote polycentric governance. Each of these principles may apply more directly to one of the three capacities depending on the context. For example, response diversity has been shown to play a key role in the persistence of coral reefs following a disturbance (Elmqvist et al., 2003). However, the seven resilience principles may also interact, for example, broadening participation among diverse stakeholder groups can support enhanced learning and, in some cases, help promote polycentric governance (Biggs et al., 2015).

The concept of integrated social-ecological systems has since become central to resilience thinking. Many of the challenges facing water systems today arise from the complex interplay of global drivers such as climate change and population growth (Gupta, 2015), interacting with local and regional processes of land use and decision making (Keys & Wang-Erlandsson, 2018), which in turn are influenced by people's needs and values. Water systems, and water system governance, are integrated social-ecological systems, a type of complex adaptive system (Falkenmark, 2017; Falkenmark, Wang-Erlandsson, & Rockström, 2019; Keys & Wang-Erlandsson, 2018). Keys and Wang-Erlandsson (2018), for example, go beyond applying this type of social-ecological systems thinking to rivers and lakes and apply it to atmospheric moisture flows, specifically the social dynamics of moisture recycling. The number and degree of interactions across social and ecological components and across scales, helps to explain why there are no easy, one-size-fits-all solutions to addressing water-related risks or solving the looming global water crisis (Akhmouch, Clavreul, & Glas, 2018; Gupta, 2015; Rockström et al., 2014). As explained by Gupta (2015), the hydrological system is one system, local water challenges add up to global issues and global drivers will ultimately influence the local situation, “there is probably no such thing as a single consolidated water problem” (p. 419).

3 Unpacking the Key Concepts

How resilience is conceptualized continues to be refined and is presently informed by three main concepts: persistence, adaptability, and transformability (Folke, 2006; Folke et al., 2010; Folke et al., 2016; Walker & Salt, 2006). We unpack each of the key concepts: persistence, adaptive capacity, and transformative capacity, in turn, drawing on and synthesizing the literature that describes the genesis, evolution, and important underlying factors for each concept.

3.1 Persistence

Persistence has been an integral component of the definition of resilience from the start. Holling (1973) first described resilience as the capacity to persist within a particular domain in the face of change. While the exact definition may vary, persistence, also referred to as absorptive capacity (see for example Béné, Newsham, Davies, Ulrichs, & Godfrey-Wood, 2014; Brown, 2016), typically refers to a system’s general capacity or ability to withstand or absorb stresses and shocks in order to avoid crossing a threshold into an alternate state (Baharmand, Boersma, Meesters, Mulder, & Wolbers, 2016; Folke, 2006; Miller et al., 2010; Perrings, 1998). In simple terms, Folke et al. (2010) describe persistence as a buffering capacity “for conserving what you have and recovering to what you were” (para. 23).

Initially, where recovery and constancy were the focus of engineering resilience, persistence was a key consideration of ecological and social resilience (Béné et al., 2014; Folke, 2006). Today, persistence is commonly considered one of three elements of social-ecological resilience, although it does not receive the same level of attention as adaptive capacity and transformability in current literature (Baharmand et al., 2016; Folke, 2006; Miller et al., 2010; Walker et al., 2004).

Taking this further, Herrfahrdt-Pähle and Pahl-Wostl (2012) list persistence as one of three types of change in social-ecological systems, with adaptation and transformation being the other two types of change. In their work on institutional resilience and the tension between the concepts of continuity and change, the authors explain that persistence refers to “an institutional system that changes only incrementally after a disturbance” (Herrfahrdt-Pähle & Pahl-Wostl, 2012, para. 9). Accordingly, persistence is described by the authors as being associated with a greater level of continuity than the other two types of change. Béné et al. (2014) echo this characterization noting that social-ecological resilience is the result of absorptive (persistence), adaptive (incremental adjustment), and transformative (transformational responses) capacities which vary in terms of their resulting intensity of change, from least to greatest.

Several factors have been identified as important for persistence. These factors are listed in Table 1 and are described in more detail below.

Disturbances are a natural, inherent part of ecosystem dynamics. They create variation and allow for renewal in systems. History offers many examples of systems that have been set up for catastrophic failure when variability has been restricted or eliminated. The Mississippi River basin, for example, has seen considerable reduction in natural, lateral flow variation as a result of channelization and the construction of locks and levees, the same alterations which allowed development in floodplains (Holling & Meffe, 1996). These changes reduced the resilience of the system and are responsible for devastating floods in the basin (Gunderson, 2010). Respecting and allowing for variability in a system is critical for avoiding such situations. Reducing variability reduces options for responding to future environmental changes.

Table 1 Persistence factors

Factor	Description	Sources
Variability	Systems which are managed to be relatively constant over time, in the face of variation in the environment, tend to have low resilience and do not easily recover after they have been changed	Berkes, Colding, and Folke (2003), Levin (1998), Nyström, Folke, and Moberg (2000), and Walker (1993)
Release	Allowing some moderate level of release (i.e., accumulated resources are released and exhausted) to occur on a more routine basis prevents the disruption of the structure and function of the overall system	Costanza, Wainger, Folke, and Maler (1993), Curtin and Parker (2014), and Perrings, Folke, and Mäler (1992)
Diversity and redundancy	Species diversity, functional diversity, response diversity, and redundancy (i.e., overlapping functionality) all play a role in enabling a system to persist	Berkes et al. (2003), Elmqvist et al. (2003), Folke (2003), Hammer, Jansson, and Jansson (1993), Levin (1998), Nyström et al. (2000), Peterson, Allen, and Holling (1998), and Stirling (2007)
Connectedness	Connectedness refers to the degree to which component parts of the system interact and move across ecological and social landscapes. Under-connected systems may be unable to respond to a change or threat, over-connected systems may seem more stable but can actually be more brittle and prone to sudden collapse	Curtin and Parker (2014), McClanahan, Polunin, and Done (2002), Nyström et al. (2000), and Peterson (2000)
Memory	Memory is the accumulated experience and history of the system, providing the sources for self-organization	Adger, Hughes, Folke, Carpenter, and Rockström (2005), Berkes et al. (2003), Brand (2005), Cumming et al. (2005), and Curtin and Parker (2014)

Allowing more frequent, moderate levels of release at specific scales prevents the disruption of the structure and function of the overall system and contributes to a system's persistence (Curtin & Parker, 2014). In fire-adapted ecosystems, many plant species only regenerate following a fire as the heat from the fire is the necessary trigger for the release of seeds (Gunderson, 2010). Democratic systems that require starting over every few years by voting provide another example of moderate release resulting in long-term persistence.

Diversity, in several forms, is considered to play an important role in enabling a system to persist. Biological diversity allows for diversity of functional groups, and diversity in species and populations within those functional groups. Species and population diversity within functional groups not only provides redundancy, essentially a form of insurance in dynamic systems undergoing change, but also response diversity. Response diversity refers to the differences in the responses of species within the same functional groups. As explained by Elmqvist et al. (2003), response diversity "enables the community to keep performing in the same complimentary way in the face of stresses and disturbances" (p. 490). Other forms of diversity that are associated with social sub-systems, such as livelihood diversity, have also been shown to influence a system's resilience and more specifically its capacity to persist (Hanazaki, Berkes, Seixas, & Peroni, 2013).

Degree of connectedness is key to persistence and varies from system to system. Being over- or under-connected can present issues. In coral reef systems, McClanahan and others (2002) describe reef populations that are consistently and reliably replenished with larvae transported from other reefs by ocean currents, as being strongly connected to their sources of larvae. This degree of connectedness is important for persistence. For very isolated reefs, replenishment depends on the reef's own supply of larvae and juveniles (McClanahan et al., 2002).

A system's memory refers to the accumulated experience and history of the system, and is imperative for the capacity of persistence (Berkes et al., 2003). Memory facilitates reorganization and renewal and has both ecological and social components (Adger et al., 2005). Defined by Berkes et al. (2003), ecological memory is "the composition and distribution of organisms and their interactions in space and time, and includes the life-history experience with environmental fluctuations", while social memory refers to the "long-term communal understanding of the dynamics of environmental change and the transmission of the pertinent experience" (pp. 20–21). Ecological memory includes biological legacies that survive disturbances, seed banks, mobile species, and refuges (Adger et al., 2005; Brand, 2005; Cumming et al., 2005). Contributions to social memory include customs and taboos, laws, knowledge keepers, elders, formal archives, and libraries (Cumming et al., 2005).

3.2 Adaptive Capacity

The term adaptive capacity can be traced back to the natural sciences and evolutionary biology, in which the features of an individual, species, or population that promote adaptation or fitness have received attention (Plummer & Armitage, 2010). The field of anthropology, and the anthropologist Julian Steward in particular, is credited with laying the groundwork for understanding how humans adapt to their environment (Engle, 2011; Plummer & Armitage, 2010). The general concept has since been taken up by social scientists in human ecology, geography, and applied areas including political ecology, climate change studies, resilience thinking, and social-ecological systems. Literature on adaptive capacity specifically within the context of social-ecological systems and resilience has grown rapidly (Johnson & Becker, 2015). Adaptive capacity, from a social-ecological systems and resilience perspective, refers to, "the ability of the social-ecological system to learn and to adjust its responses to the impacts of external drivers and internal change. The system undergoes change while still retaining its system identity – function, structure and feedbacks" (Berkes, 2017, p. 1232). Folke, Hahn, Olsson, and Norberg (2005) explain that systems with high adaptive capacity have the ability to reconfigure themselves when faced with change without experiencing significant declines in crucial functions for that system, it involves a balance between sustaining and developing (Plummer & Armitage, 2010).

The connection between adaptive capacity and social-ecological resilience is not described consistently among scholars (Gallopín, 2006). Walker et al. (2002) and Smit and Wandel (2006) have pointed out that some authors use the terms "adaptive capacity" and "resilience" or "social resilience" interchangeably. Berkes (2017) writes that adaptive capacity has long been considered the "core of resilience". Often, however, adaptive capacity is explored as one of several aspects, dimensions, or properties of resilience. For example, Brown (2016) considers three dimensions of social-ecological resilience, absorptive capacity, adaptive capacity, and transformative capacity.

The question of what determines adaptive capacity in relation to social-ecological resilience also elicits a variety of responses in the resilience literature. Here we draw on the broad social-ecological systems literature rather than focusing in on a specific subset, such as that related to climate change.

The work of Folke et al. (2003) is frequently cited in the resilience literature when discussing adaptive capacity for building resilience (see for example Olsson, Folke, & Hahn, 2004; Armitage, 2005; Berkes, 2007; Plummer & Armitage, 2010; Zhou, Wang, Wan, & Jia, 2010). The authors identified four critical factors that interact across temporal and spatial scales and that seem to be required to foster adaptive capacity in social-ecological systems, particularly during periods of crisis (Folke et al., 2003; Folke et al., 2005; Plummer & Armitage, 2010). As summarized by Armitage (2005), the four factors are:

> (1) learning to live with uncertainty and change by allowing and/or encouraging small-scale disturbance events before there is a buildup of pressures leading, inevitably, to some sort of collapse; (2) supporting and promoting diversity and highlighting the positive connection between diversity and redundancy, both biological and institutional, as a risk-diffusion mechanism; (3) combining different types of knowledge, including Western scientific knowledge and local and/or traditional knowledge across multiple scales; and (4) maintaining opportunities for self-organization of social, institutional/organizational and ecological systems in the direction of sustainability. (p. 706)

Table 2 builds upon the foundational work by Folke et al. (2003) and reflects the proliferation of more recent scholarship (Siders, 2019) regarding factors influencing adaptive capacity.

Table 2 Adaptive capacity factors

Factor	Description	Sources
Capitals	Human, organizational and social, political, financial, natural, information and technology, material resources and infrastructure	Engle and Lemos (2010), Gupta et al. (2010), Koontz, Gupta, Mudliar, and Ranjan (2015), and Siders (2019)
Nurturing diversity for reorganization and renewal	Supporting and promoting diversity and highlighting the positive connection between diversity and redundancy, both biological and institutional, as a risk-diffusion mechanism	Folke et al. (2003) as cited in Armitage (2005), Adger et al. (2005), Berkes (2007), and Siders (2019)
Maintaining opportunities for self-organization	Maintaining opportunities for self-organization (i.e., the development of complex adaptive systems based on the components, interactions and autonomous processes of the system) of social, institutional/organizational and ecological systems in the direction of sustainability	Folke et al. (2003) as cited in Armitage (2005), Berkes (2007), Gupta et al. (2010), and Siders (2019)
Living with uncertainty and change	Learning to live with uncertainty and change by allowing and/or encouraging small-scale disturbance events before there is a buildup of pressures leading, inevitably, to some sort of collapse	Folke et al. (2003) as cited in Armitage (2005), Berkes (2007)
Combining types of knowledge	Combining different types of knowledge for learning, including Western scientific and local and/or Indigenous knowledge across multiple scales	Blackstock (2001), Folke et al. (2003) as cited in Armitage (2005), McGregor (2004), Tengö, Brondizio, Elmqvist, Malmer, and Spierenburg (2014), and Tobias and Richmond (2016)
Institution building	Commitment to supporting a long-term institution-building process and/or encouraging appropriate institutions that permit and incorporate evolutionary change and learning	Armitage et al. (2009), Lemos, Boyd, Tompkins, Osbahr, and Liverman (2007), Plummer and Armitage (2010), and Siders (2019)
Trust building	Building trust through collaboration, institutional development, and social learning; also an important factor in social capital	Armitage et al. (2009), Gupta et al. (2010), Koontz et al. (2015), Plummer and Armitage (2010), and Siders (2019)
Social learning	Collaborative or mutual development and sharing of knowledge by multiple stakeholders (people and organizations) through learning-by-doing	Armitage et al. (2009), Gupta et al. (2010), Koontz et al. (2015), Plummer and Armitage (2010), and Siders (2019)

Another term for capitals is resources. Resources come in many different forms, but they all have one thing in common, they can be mobilized in order to implement adaptation measures (Gupta et al., 2010). The most obvious example of this is financial capital, the “availability of financial resources to support policy measures and financial incentives” (Gupta et al., 2010, p. 462). As an example, a local government or watershed authority may offer financial incentives to rural residents for naturalizing riparian areas on their property in an effort to enhance flood water retention. Where resources are limited, so too is adaptive capacity.

As explained by Berkes (2007), diversification is the universal strategy for reducing risks and increasing options for coping with shocks and stresses. Simply put, nurturing diversity is the equivalent of not putting all your eggs in one basket. Local economies that are largely dependent on one or a few sectors, especially climate sensitive sectors (e.g., tourism, agriculture, fisheries), may have a limited capacity to adapt. Economic diversification could take the form of introducing new sources of income in a different sector, or promoting adaptation measures within the existing sector(s).

Folke (2006) described self-organization as the opposite of either "lack of organization, or organization forced by external factors" (p. 260). Maintaining opportunities for self-organization of social, institutional/organizational, and ecological systems in the direction of sustainability may involve a preference for strategies that support decentralization and voluntary action (Hahn & Nykvist, 2017). As Ostrom, Burger, Field, Norgaard, and Policansky (1999) point out, "[n]ational governments can help or hinder local self-organization" (p. 281), for example by choosing to recognize and legitimize self-organized governance arrangements, or not.

Many societies have successfully learned to live with uncertainty and change by developing adaptations to deal with small-scale disturbances, rather than attempting to stifle change. Flood-adapted communities, like those in rural Bangladesh, are a great example (Berkes 2007). Flooding during seasonal storms has always been a reality in Bangladesh, and communities are quite adept at dealing with these floods (Hoque & Moore, 2009). Climate change, however, presents additional challenges to these communities and brings with it greater uncertainty. Nevertheless, communities are attempting to learn new ways to adapt to their changing and more unpredictable environment (e.g., local farmers learning to adopt new patterns of livelihood such as aquaculture and floating vegetable gardens) (Hoque & Moore, 2009).

Social-ecological systems are tremendously complex. Different types of knowledge (e.g., Indigenous and local knowledge systems, Western scientific) offer different insights into how a system has behaved in the past, how it responds to disturbance, how various adaptations have fared, and so on. By combining these types of knowledge, a richer pool of information and experiences can be drawn from, and much more can be learned about the system than would be possible otherwise (Robinson & Berkes, 2011). As described by Tengö et al. (2014), cross-fertilization among a diversity of knowledge systems can also improve the "capacity to interpret conditions, change, responses, and in some cases causal relationships in the dynamics of social-ecological systems".

Institutions play an important role in adaptive capacity, yet there is no standard blueprint for what makes an effective institution (Armitage et al., 2009). Adaptive capacity can be enhanced with commitment to, and support of, a long-term institution-building process. It is important for actors to recognize that there is no end point, institutional arrangements require continuous cultivation and should permit evolutionary change and learning to be incorporated (Lemos et al., 2007; Armitage, Berkes, Dale, Kocho-Schellenberg, & Patton, 2011). In Northern Kenya, institution building is a specific intervention being led by the Kenyan NGO Pastoralist Integrated Support Programme (PISP) to enhance the adaptive capacity of Gabra communities (Robinson & Berkes, 2011). This includes working with local stakeholders to form water user associations that work with, and through, traditional organizations and institutions (Robinson & Berkes, 2011).

As argued by Folke and others (2005), trust is the basis of all social institutions, it "makes social life predictable, it creates a sense of community, and it makes it easier for people to work together" (p. 451). This sentiment is echoed by Lockwood, Raymond, Oczkowski, and Morrison (2015) who point out that trust is important in facilitating coordinated actions and managing risks and conflict in complex systems. There is no recipe for trust building, and it is far from instantaneous (Armitage et al., 2009). It takes time to establish trust among individuals and groups, especially in cases with deeply rooted histories of distrust (Armitage et al., 2011; Folke et al., 2005). Repeated participation and interaction through collaborative arrangements, as well as a commitment to open communication are just some of the ways identified to help build trust over time (Armitage et al., 2009; Lockwood et al., 2015). However, it is also important to note that trust, once built, can be quickly eroded (Armitage et al., 2009; Folke et al., 2005).

Social learning refers to learning that occurs through an iterative process of engagement and reflection, during which people "interact with each other, producing knowledge together that is relational and collectively oriented" (Koontz et al., 2015, p. 144). In the process of social learning, individuals are able to share their experiences with change, including any successful or unsuccessful adaptations, which can help inform the development of suitable strategies for dealing with ongoing changes (Koontz et al., 2015).

3.3 Transformative Capacity

The recognition that when systems are highly vulnerable to diminishing resilience, or are highly resilient but in ways that lock-in unsustainable and unjust pathways, there may be a need to transform, has been growing for nearly two decades (Feola, 2015; Folke, 2006; Gunderson & Holling, 2002; O'Brien, 2012; Walker, Gunderson, Kinzig, & Folke, 2006). The definition of transformation has evolved over time, however, the idea of shifting to a new system has remained at the core. Early on, Walker, Holling, Carpenter, and Kinzig (2004) defined transformability as the "capacity to create a fundamentally new system when ecological, economic, or social (including political) conditions make the existing system untenable" (para.1). Today, transformation is defined as altering the way that: authority, power, and resources are structured and flow through social systems, roles and routines are practiced, groups are structured, norms, values, and beliefs underpin those structures and processes, and the way that all of these are connected to natural capital, ecosystem services, and the non-human across multiple scales (Moore et al., 2014; Olsson, Moore, Westley, & McCarthy, 2017; Westley et al., 2011).

Given the broad systemic shifts expected to be involved in transformation, a strong emphasis on transformative agency, social-ecological innovation, and the contested processes – sometimes even violent ones – that seem to be part of many transformations began to be conceptualized and empirically studied (Bahadur & Tanner, 2014; Brown, 2016; Moore et al., 2014; Olsson et al., 2006; Olsson, Galaz, & Boonstra, 2014; Pelling & Manuel-Navarette, 2011; Westley et al., 2013). Stemming from these insights, it became clear that transformative capacities were needed within systems to make such fundamental changes, and to navigate the phases of a transformation (Brodnik & Brown, 2018; Hölscher, Frantzeskaki, Mcphearson, & Loorbach, 2019; Wolfram, 2016) such as preparing the system for change, finding opportunities within different opportunity contexts, and navigating the transition from the existing system to a new one (Brodnik & Brown, 2018; Olsson et al., 2006; Tschakert & Dietrich, 2010; Westley et al., 2013). What has been less clear, is the distinction between adaptive and transformative capacities, which this synthesis begins to address.

Although difficult to find explicit evidence or discussion of the idea, one of the most essential capacities could be expected to be knowing whether to mobilize adaptive or transformative capacities; that is, knowing which is most appropriate and when. All of the adaptive capacities previously described will be essential to transformation. A transformation will require capacities for trust building, institution building, engaging with multiple ways of knowing, living with uncertainty, and having latent capital available in open networks (Wilson, Pearson, Kashima, Lusher, & Pearson, 2013). However, as Eakin et al. (2016) assert, there are some additional capacities important to transformation (Table 3).

The first factor for transformative capacity is connected to an overall agent-structure relationship. As Westley et al. (2013) contend, complex social-ecological systems cannot be controlled and yet, the agency of individuals is essential for generating novelty and transforming systems. Systems are "not just something done to us" (Moore et al., forthcoming), nor are they held in place by only one set of actors or one specific structure (Westley, Zimmerman, & Patton, 2006). Being able to see, realize, and enact one's own agency within the system can be a challenging but necessary capacity for transformation (Olsson, 2017; Westley et al., 2013).

Numerous scholars highlight the importance of ensuring there is ongoing experimentation and a capacity to innovate, with social-ecological innovation described as a multi-phase process quite distinct from the capacities involved in technological innovation (Olsson et al., 2017). Along with experimentation, it is crucial that individuals, networks, and organizations – again, including the human and non-human – have the capacity for learning, unlearning, and (re)organizing around new basins of attraction or the alternative trajectories. The social-ecological system resilience and complexity perspective also recognizes that transformation involves emergence. Emergence refers to the novel element or system dynamic that stems from the interaction of two or more "parts" of a system. The result is that the overall system is qualitatively different from before that interaction (Mittleton-Kelly, 2003). Having the capacity to navigate the process and appearance of emergence in a system is suggested as important to transformation (Moore et al., 2018; Schlüter et al., 2019).

Table 3 Transformative capacity factors

Factor	Description	Sources
See and exert your own agency that is embedded within the system	Any individual's actions will have an effect on the system since they are part of social and social-ecological systems, not simply outside of them	Olsson (2017), Westley et al. (2013), and Ziervogel, Cowen, and Ziniades (2016)
Social-ecological innovation and experimentation	Need to generate the "invention" or novelty in the system, but also select, adopt, and institutionalize	Folke et al. (2010), Gunderson, Folke, and Janssen (2006), Moore et al. (2014), Olsson et al. (2014), Westley et al. (2011, 2013), Wilson et al. (2013), and Wolfram (2016)
Skills for learning, unlearning, reorganizing	Given that transformation moves towards the unknown, learning is essential for understanding the dynamics around an actor as they unfold. However, given that knowledge generated in the old system may be a barrier for new, alternative ideas or paradigms, unlearning can also be important	Brodnik and Brown (2018), Folke et al. (2010), Marshall, Park, Adger, Brown, and Howden (2012), Moore et al. (2014), Moore, Olsson, Nilsson, Rose, and Westley (2018), and Wolfram (2016)
Navigate emergence	Recognize, respond, and navigate the experiences of a "qualitatively different whole" or fundamentally different system trajectory	Moore et al. (2018) and Schlüter et al. (2019)
Systems reflexivity	To be able to see, interrogate, and re-imagine the structures that sustain the existing system dynamics	Apgar, Allen, Moore, and Ataria (2015), Moore et al. (2018), and Wolfram (2016)
Maintain flexibility in sense of place and occupation	Given the attachment that individuals have to place and occupation, changing those in fundamental ways requires flexibility that ensures continuity in some cultural, place-specific values	Adger, Barnett, Brown, Marshall, and O'Brien (2013) and Marshall et al. (2012)
Engage with difference and diversity	Rather than focusing only on allies and like-minded individuals, finding generative ways to work with diverse ways of knowing or with those with differing views	Tschakert and Dietrich (2010)
Envision alternatives, create new narratives and meaning making	Being able to imagine a different kind of future and create agreement among actors for that vision	Adger et al. (2013), Merrie, Keys, Metian, and Österblom (2018), Milkoreit (2017), Moore et al. (2014), and Westley et al. (2013)

Navigating the changes that are not only deliberately and strategically enacted, but which also may emerge at different scales will also require actors to have emotional flexibility in their responses, and some form of flexibility with regards to attachments in sense of place and occupation could be critical (Adger et al., 2013; Marshall et al., 2012). Sense of place refers to the level of attachment that people have to communities and environments in which they live, and can include the identity they associate with their occupation (Adger et al., 2013). While sense of place can serve as a form of adaptive capacity, Marshall et al. (2012) demonstrate that it may hinder transformative capacity when people are so attached, any change to a place is refused and resisted. Therefore, some type of flexibility that ensures that transformation does not disrupt or discontinue the identities that are intertwined with sense of place in ways that diminish emotional, psychological, relational, and/or financial wellbeing is an essential, albeit complex capacity (Adger et al., 2013). In line with the principles of resilience, transformation will also rely on diversity (Tschakert & Dietrich, 2010). However, engaging with diversity in meaningful ways and not only focusing on those that are like-minded is difficult work. In fact, the practical advice to those trying to achieve change is often to find allies and not to worry about those who may initially disagree. Having substantial capacity within the system to not just maintain diversity but to engage and work with it over time, when necessary, is critical. One outcome of this diversity may be the envisioning and meaning making (i.e., creating agreement among actors) of alternative futures, a capacity also essential to transformation according to several scholars (Merrie et al., 2018; Milkoreit, 2017).

4 Distinctions, Overlaps, and Tensions Among Factors

The three constructs – persistence, adaptive capacity, transformative capacity – are all essential to the resilience of a system. Through the exercise of identifying the underlying factors of each construct, it is evident that there are areas of overlap. Several factors are important for multiple constructs, though they may not be expressed in the same manner for each capacity. Focusing on persistence, adaptive capacity, and transformative capacity factors in particular constellations is important depending on the desired goal, as it shapes/influences the outcomes. At the same time, the specific context surrounding a social-ecological system, may determine which factors are more or less relevant in terms of their contribution to resilience, at any given time (Hanazaki et al., 2013).

Persistence and adaptive capacity factors show the greatest degree of overlap. Each of the five persistence factors identified (Table 1) have connections to one or more adaptive capacity factors (Table 2). Variability and release, for example, overlap with the adaptive capacity factor of living with uncertainty and change. Allowing a system to experience variation and some degree of release is precisely what the concept of accepting and learning to live with uncertainty and change is about. While there is a high degree of overlap apparent between these capacities, there are nuances or distinctions that can be made between the factors. As an example, there is obvious overlap between ‘diversity and redundancy’ and ‘nurturing diversity for reorganization and renewal’. However, some aspects of diversity are more relevant to persistence and others apply more to adaptability. For example, genetic diversity is key to adaptive capacity in an evolutionary sense, while something like response diversity would play a more important role in enabling a system to persist (i.e., by way of the range of possible reactions).

While the factors underlying adaptive capacity are also essential to transformation, although in slightly different ways, there are additional factors unique to transformative capacity that make it the most distinct of the three constructs. Given the nature and degree of change associated with transformation, this fact is not surprising. Deliberate transformations involve agency and a social process of learning and innovation (Luthe & Wyss, 2015). For these reasons, factors such as emotional flexibility, exerting agency, and envisioning alternatives are unique to transformative capacity.

Persistence Case Study

The Niagara River is a transboundary river, shared by Canada (Ontario) and the United States (New York), that connects Lake Erie with Lake Ontario (Fig. 2). It is a river that has a wide range of uses, from drinking water to recreation to power generation and industry. However, it is most notably known as the source for the Niagara Falls, an iconic tourist attraction in Ontario and New York. The Niagara River was identified as one of 43 Great Lakes Areas of Concern in 1987 under the Great Lakes Water Quality Agreement – a bilateral agreement to support the restoration of water quality – and a Remedial Action Plan was developed. The Remedial Action Plan focuses on identifying and remediating 'beneficial use impairments' (BUIs): any "reduction in the chemical, physical or biological integrity of the Waters of the Great Lakes" that impedes the ability to enjoy and use the waters (GLWQA, 2012, p. 21). These BUIs are assessed against local goals and targets set to restore beneficial uses of the river. This case study is an example of a focus on persistence – where the system is degraded and governance and management activities aim to restore the system to a previous, more desirable state and protect it (GLWQA, 2012).

This process of remediation and restoration has been ongoing since 1987 and continues today. Since the Niagara River Remedial Action Plan's inception and identification of nine BUIs (Ontario Ministry of Environment and Energy [OMEE], Environment Canada, Ontario Ministry of Natural Resources [OMNR], & Fisheries and Ocean Canada, 1993), substantive progress has been made, with five remaining BUIs (Niagara River Remedial Action Plan, 2019). This is the case not only in the Niagara River, but in Areas of Concern across the Great Lakes. Some of these Areas of Concern have removed all BUIs and no longer need to participate in the Remedial Action Plan program. Accordingly, it is clear that the actions taken by actors on these landscapes – in the Niagara River this includes multiple levels of government, non-governmental organizations, and others – are having a positive impact.

When we review this case study in light of the factors for persistence, adaptive capacity, and transformative capacity, we identify that activity in the Niagara River via the Remedial Action Plan is directly focused on several persistence factors (Table 1). First, a focus on 'Diversity and Redundancy' is evident in several of the BUIs (e.g., 'Degradation of fish/wildlife populations'

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and 'Degradation of phytoplankton and zooplankton populations'). The Remedial Action Plan aims to restore these populations where degraded, building back diversity and redundancy into the system and ensure their integrity remains over time. Second, there is a focus on 'Connectedness', evidenced by the 'Loss of fish and wildlife habitat' BUI. By restoring habitat to an extent that fish and wildlife populations recover (see previous point about diversity and redundancy), connectedness must be present. From a governance and management perspective, implementation and oversight of the Remedial Action Plan process requires participation by a range of actors, sharing information and coordinating activities (Niagara River Remedial Action Plan, 2019; OMEE et al., 1993). Accordingly, 'Connectedness' is evident in both the social and ecological systems.

While there is overlap among factors for persistence, adaptive capacity, and transformative capacity ('Diversity and Redundancy' and 'Connectedness' occur in some form in all three concepts), it is clear from the Great Lakes Water Quality Agreement and Remedial Action Plan documents that the underlying intention of the activities in the Niagara River are focused on persistence, that is, "conserving what you have and recovering to what you were" (Folke et al., 2010, para. 23). Going forward most social-ecological systems would require some degree of adaptation at different points in time even if the primary goal of management is to enable the current regime of the system i.e., its structure, function, and identity, to persist.

Fig. 2 Niagara River, Ontario. (Photo credit: Natalie Green, NRRAP, used with permission)

Adaptation Case Study

The Saint John River Basin (SJRB) is a 55,000 km^2 transboundary watershed situated in New Brunswick, Quebec, and Maine. In 2013 the Saint John River was designated as a Canadian Heritage River for its outstanding cultural values (Canadian Heritage Rivers System, 2017). WWF-Canada has been active in the basin, under the leadership of Simon J. Mitchell, to address concerns about dams and impoundments impeding environmental flows and endangered salmon populations in the Saint John River, ultimately working towards a basin that is 'healthy' in all aspects (WWF-Canada, 2011). WWF-Canada identifies a need for "a coordinated, basin-wide plan to re-establish a more natural flow regime that better balances nature's water needs with those of hydropower generation and other uses" (WWF-Canada, 2011, p. 26). Accordingly, this case study is an example of a focus on adaptation – where the system is stressed/threatened (WWF-Canada, 2016) and requires adaptive capacities, but is still providing functions and benefits that contribute to human well-being and ecosystem health. This is evident from the Canadian Heritage River designation and engagement of a range of actors in management, albeit in an approach that required further coordination.

Researchers from Brock University partnered with Mitchell to develop a baseline understanding of the actors engaged in water management (related specifically to river health) in order to begin to work toward a basin-wide approach. The research identified nine categories of actors, including governments (Canadian and US), First Nations, environmental non-governmental organizations, watershed organizations, and industry (Plummer, Baird, Krievins, & Mitchell, 2016). These actors were connected, but it was evident from the research that the provincial government held a highly central (and powerful) role in the network of actors (Plummer et al., 2016). WWF-Canada used this analysis to engage actors basin-wide in an annual River Summit, with the intention of building constructive dialogue about the SJRB and developing a shared action plan for a healthy Saint John River in time. The River Summits are engaging diverse actors in the river basin in discussions about what governance should and could be for the SJRB (Fig. 3, see especially the top left corner).

When we review this case study in light of the factors for persistence, adaptive capacity, and transformative capacity, we identify that WWF-Canada is directly focused on several adaptive capacity factors in their intent and process of hosting the River Summits (Table 2): 'Nurturing diversity for reorganization and renewal' by inviting all actors active in the basin to join the summit; 'Combining types of knowledge' by explicitly acknowledging and engaging with knowledges outside of western, scientific knowledge;

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'Institution building' by encouraging dialogue explicitly about appropriate institutions for governing the basin; and, 'Social learning' as evidenced by feedback from Summit participants, with 100% of responding participants indicating they left the Summit with a better understanding of the basin system than prior to their participation, and several participants indicating they had learned from others and developed relationships (WWF-Canada, unpublished data).

As identified earlier, there is overlap among factors for persistence, adaptive capacity, and transformative capacity, and it is important to recognize the presence of factors from each in this case. For persistence, 'Diversity and redundancy' and 'Connectedness' are two factors that resonate, though the underlying intention and emphasis of these is different – for example, connectedness for persistence is about stability and reducing fragility whereas in the case study, connectedness was about building relationships and creating conditions for social learning in order to facilitate an adaptive response to basin governance. Similarly, for transformative capacity 'Engage with difference and diversity' resonates with the case study, as does 'Envision alternatives, create new narratives and meaning making' as WWF-Canada is certainly creating new narratives in the SJRB. However, where these factors differ is again in the intention that underlies them – for transformative capacity the focus is on 'broad systemic shifts' – and the case study here shows more adaptive intentions than transformative.

Fig. 3 Graphic depiction of the discussion during the Saint John River Summit in 2017. (Figure credit: Simon J. Mitchell, used with permission)

Transformation Case Study

In the Cowichan Watershed on eastern Vancouver Island in British Columbia, Canada, a quiet transformation is unfolding. Outside of the limelight, driven by community champions of all stripes, and through perseverance, patience and partnerships, over the past decade the Cowichan Watershed Board is advancing change in how water is managed and governed, strengthening local capacity and influence, and building a foundational partnership between the Regional District (local government) and Cowichan Tribes that actively express "*reconciliation in action*."

The Cowichan Watershed is 930 km^2, with a number of communities and the city of Duncan and contains world class features including Cowichan Lake, Heritage River designation, and the Cowichan Estuary as notable features (Hunter, Brandes, Moore, & Brandes, 2014) (Fig. 4). Ongoing concerns exists around water scarcity and pollution from multiple sources, including agricultural runoff, industrial effluent, and sewage discharge.

The catalyst for action in Cowichan was a serious drought in 2003. Crisis brings opportunity. Salmon had to be moved upstream by truck because flows dropped so low; and fears ran high that the pulp mill would have to shut down (a major employer in the area) and that the Indigenous food fishery would be lost. From acrimony, tension, and despair, local *champions* realized a new path forward was necessary, especially with the emerging realization things would not get any easier with a climate in chaos.

The first step after this crisis was to develop a Cowichan Basin water management *plan*. This is not a legally binding plan, but sets out a *shared vision*, goals, objectives, and actions. In the Cowichan, planning provided the kick-start to build relationships, reveal leaders, and identify further projects and partnerships in the watershed. A key early insight was that in order to make plans stick you need to engage with governance and so the Cowichan Watershed Board (CWB) was formed in a series of phases leading up to 2010 under the wise leadership of real local champions providing direction for sustainable watershed management and to implement the Plan. From the outset, CWB has been co-chaired by Cowichan Tribes and Cowichan Valley Regional District, each deploying their respective authority. Through this model, Cowichan Tribes and the CVRD are developing a strong partnership and demonstrating a deep commitment to moving down the path of reconciliation – together (CWB, 2018).

Notable features of this commitment to reconciliation, include recognition of territory and the authority of the Cowichan Tribes throughout the watershed rather than treating it as property of the colonial government, inclusion of Cowichan language, and including Indigenous knowledge in decision making (CWB, 2018). The CWB, in a recent series of workshops, committed to a number of actions including exerting decision-making influence outside of

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legislated means and engaging in new pathways to a whole watershed health approach that centres on recognizing Indigenous authority, strengthening partnerships, and ensuring a readiness to act on opportunities as a new provincial *Water Sustainability Act* (2016) is implemented (CWB, 2018). "This shift in approach is expected to result in fundamentally different ways of making decisions about land and water" (CWB, 2018, p. 17).

Reviewing this case study in light of the factors identified in the resilience literature for persistence, adaptive capacity, and transformative capacity, it is clear that the CWB is an example where transformative factors are dominant (see Table 3). In particular, the CWB has engaged in activities that directly relate to the following factors:

- 'See and exert your own agency that is embedded within the system' in identifying specific ways in which their influence could be exerted in existing decision-making processes while building towards a transformed governance system where local and Indigenous authority is central;
- 'Navigate emergence' by carefully considering how a resurgence of Indigenous laws combined with the ways provincial and federal legislation and commitments are changing and how they might take advantage of opportunities associated with these changes to strengthen co-governance in the watershed;
- 'Systems reflexivity' through a commitment to collecting local scientific data and Indigenous knowledge, focusing on understanding and managing cumulative effects, and approaching watershed management from a holistic perspective while regularly engaging in learning and reflection events with each other and with others involved in water governance in the region;
- 'Engage with difference and diversity' through demonstrated co-governance and ongoing emphasis on strengthening partnerships; and,
- 'Envision alternatives, create new narratives and meaning making' through the resilience and governance workshops the CWB engaged in (e.g., Baird, Plummer, Moore, & Brandes, 2016; CWB, 2018) and ongoing efforts to co-govern and build meaningful collaboration.

Previous case studies identified substantive overlap in terms of the persistence and adaptive capacity factors and we see that factors like connectedness – which is a factor for all three concepts – are also present in this case. However, in this case there is a strong manifestation of factors that do not overlap, such as navigating emergence, systems reflexivity, and envisioning alternatives and creating new narratives are identifiable. These factors unique to transformative capacity are supported by an intention for transformation – that the CWB is actively preparing for and pushing the boundaries of change in their system.

Fig. 4 Cowichan Lake. (Author's own)

5 Conclusions

Approaches to water management and governance have evolved considerably. In this chapter we have argued that resilience is consequential for contemporary water management and governance. Persistence, adaptation, and transformation are central constructs of resilience (Chaffin et al., 2014; Folke et al., 2016; Pelling et al., 2015), but the relationships among has been obscure. We describe the genesis, evolution, and factors constituting each concept. Thereafter, we probe the tensions among them in terms of areas of overlap and uniqueness. We note that there is significant conceptual overlap among the three concepts, with the most overlap occurring among persistence and adaptive capacity factors, specifically in relation to diversity and connectedness. This is not surprising, as others have emphasized the concurrent nature of persistence, adaptability and transformability within a system (Folke et al., 2010; Biggs et al., 2012; Biggs et al., 2015; Helfgott, 2018; Salomon, Quinlan, Pang, Okamoto, & Vazquez-Vera, 2019). Transformability factors were the least likely to overlap with factors from the other two concepts based on the tables above. However, it is important to note that the capacities identified for adaptation are all important for transformation as well, and that the capacities we focused on in Table 3 are those required *in addition to* those identified as adaptation factors.

While largely a conceptual exercise, we draw on case studies of watershed organizations to then illustrate how the concepts manifest in the context of watershed management and governance. It is clear within the case studies that there is overlap in the concepts that constitute water resilience – as evidenced by the occurrence of factors from each – where the focus is primarily on one (e.g., adaptation case study exhibits factors related to persistence and transformation as well as adaptation). These patterns of overlap are consistent with the literature – diversity and connectedness were evident in more than one case, in fact, connectedness was a factor identified in all three cases. However, when we view their associated factors through the lens of watershed governance with a specific focus on persistence, adaptability or transformability, the underlying intent of similar factors is very different. Thus, while a factor may cut across more than one resilience construct, how that factor is considered and treated is unique to the construct.

Conceptually unpacking water resilience illuminates the myriad of nuanced considerations paramount to water scholars, practitioners, and policy-makers now and in the future. As such, it offers important advancements to past integrated approaches and contributes to the present conversation about water management and governance. While water resilience is sometimes treated monolithically, greater precision is afforded to scholars by unpacking it in terms of persistence, adaptive capacity, and transformative capacity. Specifically, the synthesis of scholarship for each construct identifies and describes the constituting factors.

From probing the relationships among persistence, adaptive capacity, and transformative capacity it is clear that the constructs central to water resilience are far from mutually exclusive. Water resilience involves all three. Despite striving for conceptual clarity, the boundaries between and among the constructs remains fuzzy. As illustrated in each of the three cases, it is the manner in which they come together or are emphasized that matters. These configurations will vary, change, and blur in practice. Water managers and decision-makers will benefit from considering the constructs in concert, being aware of their dynamism, and emphasizing the factors corresponding with the desire to persist, adapt, or transform.

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Adaptive Governance in North American Water Systems: A Legal Perspective on Resilience and Reconciliation

Barbara Cosens and Lance Gunderson

Abstract Governance lies at the heart of the capacity of water based social-ecological systems to manage resilience. Case studies of North American water basins reveal that the massive engineering of these systems have facilitated economic and social development to meet objectives of navigation, irrigation, flood control, hydropower, safe drinking water, recreation and pollution abatement. To meet these goals, the governance and management of these systems successfully stabilized key hydrologic and ecosystem processes, which in turn led to a decline in ecological resilience and adaptive capacity. While efforts to recover lost ecosystem functions within managed river systems are underway, the capacity to adapt to these restoration efforts and the system in general to ongoing climate change, is hindered by physical infrastructure, legal fragmentation and governmental inflexibility. Response to accelerating change and the inadequacy of fragmented legal regimes is apparent in emergence of self-organized governance at the problem or basin-regional scale. Such self-organization is categorized as adaptive governance or in this application, adaptive water governance. Self-organization alone will not allow adaptation to keep pace with accelerating global change and climate uncertainty. Adaptive water governance requires government facilitation to build adaptive capacity in time to respond to change and ensure that greater involvement of private actors and increased flexibility do not come at the expense of legitimacy, transparency, accountability, equity and justice.

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1 Resilience and Adaptive Capacity in Regional Scale Water Systems in the US

During the twentieth century, water management throughout the United States was successful in controlling and constraining the quantity, timing and magnitude of water flow in rivers and wetlands (Cosens & Gunderson, 2018). The initial social objectives behind the control were to provide reliable corridors for transportation and flood protection for economic growth and prosperity. As human populations grew, water supply for industry, agriculture, urban centers and the environment were added as social demands on these water resources increased. In the later third of the century, however, the consequences of controlling water resources were becoming manifest as ecosystem forms and functions began to fundamentally and often irreversibly change. With changes in ecosystem structure and function, came changes in the human and social structures as well. Recognition of the increasing connections and complexities of water management in drainage basins led to a reconceptualization of engineered and managed water systems to an understanding of them as complex, social-ecological systems (Anderies, Jansse, & Ostrom, 2004).

Complex social ecological water systems (Cosens & Gunderson, 2018) are made up of three components: ecosystems, engineered systems and social/institutional structures (Ostrom, Janssen, & Anderies, 2007). Ecosystems define the interactions and dynamics among living (biota) and non-living entities that are found in the aquatic portions of rivers, riparian zones within and along the watercourses, wetlands and terrestrial ecosystems. The engineered components of these systems include the infrastructure, and other human modifications designed to control and direct water movement. Engineered landscapes include both urban systems and agricultural ecosystems. Infrastructure deployed to control water movement to meet social goals, include large dams constructed in rivers to impound water and generate hydropower, as well as levees and dikes built to impede water movement, and contain flood waters. Canals readily and rapidly drain water from uplands and wetlands. The social and institutional components of water basins include the formal institutions (organizations and rules) that structure government through constitutions and legislation. Governmental agencies are created with decision authority to execute the mandates prescribed by law. Additionally, informal institutions, defined by stakeholders, users, NGO's emerge to represent particular social goals. Particular configurations and interactions of these components define a social-ecological regime. The use of "regime" is not intended to connote an authoritarian form of government, but rather a way of describing a system configuration that includes both components or entities and processes and procedures as a definable system state. The use of regime is more aligned with the use of ecological regimes as developed by Walker, Holling, Carpenter, and Kinzig (2004), and Rocha, Peterson, and Biggs (2015).

Particular regimes in water-based, social ecological systems are not static entities, but change over time. Historical overviews of changes in Everglades water management, for example, indicate regime transitions from a drainage era

(1880–1930), to a flood control era (1930–1970), to a water supply era (1970–1999) to an environmental restoration era (2000–present) (Gunderson, Garmestani, Rizzardi, Ruhl, & Light, 2018; Light et al., 1995). Such changes are not linear progressions through time, but rather abrupt transitions in some or all components of the systems, leading to new ecosystems, new infrastructure, new laws, new institutions (Chaffin, Craig, & Gosnell, 2014; Cosens & Fremier, 2014). Such shifts can be generated by ecological crises where new and novel ecosystems appear, from failures in extant policies, the addition of new policies as social values change, or unexpected variation in key hydrologic/ecosystemic processes (Cosens & Gunderson, 2018; Gunderson et al., 2002). Moreover, such regime shifts occur when ecological resilience is eroded (Holling & Meffe, 1996).

Adaptive capacity is the self-organized ability to respond to regime shifts in social ecological systems (Olsson et al., 2006). Adaptive capacity in complex hydrologic based social ecological systems is related to three interacting compentencies. One is the ability to respond to changes in external biophysical processes, such as increased variability in rainfall and evaporation, land use and nutrient inputs (Folke, 2006; Gunderson & Pritchard, 2002). The second involves the development of physical infrastructure (levees, pumps, dams, etc.), formal government structures, institutions and laws that provide stability and regulation. The third element is the emergence of adaptive governance (Folke, Hahn, Olsson, & Norberg, 2005; Gunderson & Light, 2006). Often adaptive governance confronts convergent, competing environmental policies generated by piecemeal, partial system representations found in environmental law (Benson & Craig, 2017; Craig et al., 2017).

The remainder of this chapter is organized in three sections. First, is an exploration and assessment to understand how ecological resilience has changed under historical management regimes. The second section describes the attributes of adaptive governance and how it emerges in response to forseen and unforeseen shifts in system regimes. The last section describes the role of adaptive governance in resolving multiple and systemic social values and goals, brought about by increasing governmental and institutional complexities in these water management systems.

2 Assessing Ecological Resilience in Managed Water Regimes

Changes in water management regimes were studied in six social ecological systems (Table 1 and Fig. 1). These systems cover a range of geographic, climatic, topographic and demographic settings across the United States (Cosens & Gunderson, 2018). This project engaged ecologists, legal scholars and human geographers to assess of the resilience of North American water systems (Cosens & Gunderson, 2018).

The Anacostia River is a relatively small basin situated in the State of Maryland in the mid-Atlantic region of the US. The Anacostia flows through the US Capitol,

Table 1 North American study basins showing area, average flow, rainfall, land uses political units

Name basin/ Watershed	Basin area (km^2)	Average flow (m^3/s)	Mean rainfall (cm/year)	Primary land uses	Political Units
Anacostia River	456	1.5	104	Urban/Suburban Small scale agriculture	United States State of Maryland, Washington DC
Columbia River	668,000	7500	20–250[a]	Agriculture, Urban settlements, Conservation	United States, States of Washington, Oregon, Montana, Idaho, Wyoming, Nevada, Utah Canada, Province of British Columbia, Native Americans First Nations
Everglades Basin	28,205	12	157	Urban/ surburban, Agriculture Conservation (National Park)	United States State of Florida Native Americans
Klamath River	40,790	484	53–98[a]	Agriculture, Conservation	United States, States of Oregon and California Native Americans
Middle Rio Grande River	72,000	41	24	Urban Small scale agriculture	United States, States Colorado, New Mexico, Texas Mexico Rio Bravo Native Americans
Central Platte River	219,916	199	74	Agriculture Conservation	United States, States of Nebraska, Colorado and Wyoming

Modified from Cosens and Gunderson (2018)
[a]Ranges in mean annual rainfall across a basin

Washington DC, where it joins the Potomac River before draining into Chesapeake Bay. The Anacostia basin is primarily an urban dominated watershed and is governed by local, state and federal institutions (Arnold, Green, Decaro, Chase, & Ewa, 2014).

The Everglades wetlands are located in a subtropical climate of southern Florida, characterized by wet summers and mild, dry winters. High rainfall and little topography interact to create wetland landscapes that are currently supporting conservation goals (Everglades National Park), agricultural production and urban development. The Everglades are managed by a consortium of local authorities, state water management districts and federal institutions (Gunderson et al., 2014).

A drier and continental climate combines with a large drainage basin to produce seasonal flows in the Platte River. Water from the shallow, braided central Platte River is used to irrigate crops, while providing conservation benefits to migratory birds, under a combined state and federal management regime (Birge et al., 2014).

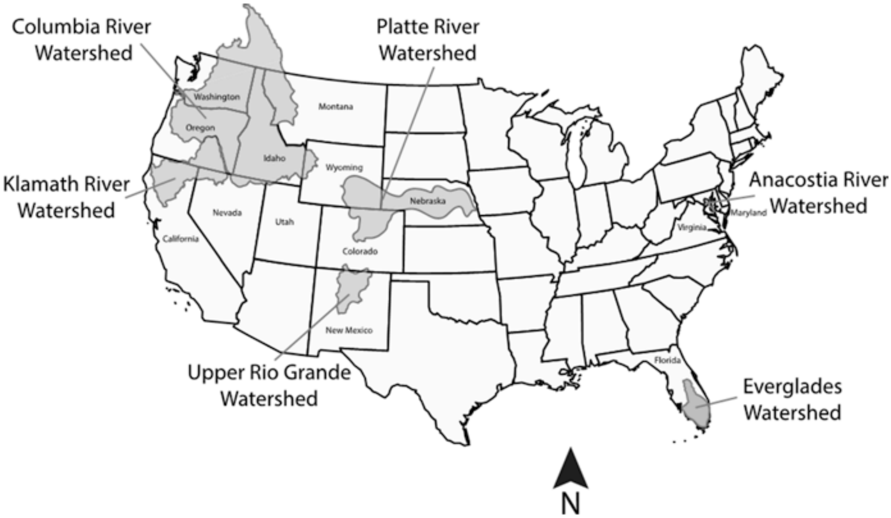

Fig. 1 Location of six study areas used in assessing adaptive capacity and adaptive governance of water management. The gray areas represent approximate drainage boundaries for each hydrologic system. (Cosens and Gunderson 2018). Used with permission.

In the arid US southwest, the Middle Rio Grande River provides water supply to urban areas in New Mexico, as well as modest agricultural diversions. The middle Rio Grande is managed to meet water needs of two nations (US and Mexico), multiple states (Colorado, New Mexico and Texas), as well as Native American and local needs (Benson, Llewellyn, Morrison, & Stone, 2014).

The two western river systems include the Klamath River (Chaffin, Craig, et al., 2014) and the Columbia River (Cosens & Fremier, 2014). These basins support urban supply, agriculture, transportation, hydropower, anadromous fisheries and conservation efforts. The Klamath River is used by Native Americans, as well as a federal irrigation project and hydropower interests, and lies within the states of Oregon and California. The Columbia River is managed cooperatively across two nations (Canada and US) seven US states, one Canadian province, with fifteen Native American tribes in the US and fifteen First Nations in Canada with claims to land and water and efforts are underway to restore salmon runs while maintaining the massive hydropower system.

All of the current water management regimes in the six study basins have been defined by policies that reflect cumulative social goals and objectives. Common social objectives that date back hundreds of years and drove the trajectory of development across these systems were navigation, flood control, and water supply for agricultural and urban sectors (Cosens & Gunderson, 2018). The use of water courses for hydropower, pollution abatement, wildlife and biodiversity conservation for the most part are relatively recent, mainly beginning in the mid-twentieth century.

Historically, policy success and social goals have been achieved through engineering structures and management regimes that control the timing, distribution, depth and flow in these water courses. The technology consists of dams, drainage canals and embankments or levees to constrain and control flood waters. For example, over 2500 miles of levees and canals have been constructed in the Everglades to drain the area for agricultural and urban development (Light et al., 1995). The major dam infrastructure in the Columbia River is the largest producer of hydropower in North America, and these dams are operated to achieve flood control, hydropower, navigation and irrigation (Cosens & Fremier, 2014). Across the cases, federal planning and investment created most of this infrastructure, which has been beneficial to agricultural, industrial, urban interests, as well as other forms of economic development. The capacity to store and release water through control structures has been used to modify and delay seasonal pulses such as spring floods associated with snowmelt or summer flooding associated with cyclones in Florida. This storage has modified flows that used to fluctuate seasonally to ones that are much more even throughout the year. While success at controlling aspects of water movement has achieved policy goals with social and economic benefits, it has come at a cost to the environmental and ecological dimensions of these water management regimes.

Holling (1973) proposed the term "ecological resilience" to describe the suite of processes that mediate the self-organization of ecosystems into alternative regimes or system states. Since that time, ecological studies have documented and described the existence of alternative ecosystem states or regimes (Folke et al., 2004; Gunderson & Pritchard, 2002). All of the six case studies have demonstrated examples of ecological regime shifts induced by human engineering. Such environmental changes have been described as the pathology of resource management (Holling & Meffe, 1996), a recognition that managing key ecosystem processes for stability may erode ecological resilience.

Examples of such ecological regime shifts from the case studies include landscape level changes in the Everglades from sawgrass marshes to cattail marshes (Gunderson & Pritchard 2002; Gunderson, Garmestani, Rizzardi, Ruhl, & Light, 2014), changes in riparian vegetation along the Middle Rio Grande River (Benson et al., 2014), Platte River (Birge et al., 2014), Columbia River (Cosens & Fremier 2014), and Klamath River (Chaffin, Craig, et al., 2014).

Another shift in ecosystem form and function occurred in those systems where large-scale dams were built. Dams have altered the movement of water, sediments, and migratory fish, and contributed to the endangerment of aquatic species in the western rivers (Klamath, Columbia, Platte and Rio Grande). Dams can also change the temperature and flow regimes in the river system, changing sediment movement and deposition critical to biotic habitats (Platte River).

Perhaps the most ubiquitous regime shift associated with water management is captured by the endangerment of species, to which the US Endangered Species Act (1973) supplies the most common legal response in the basins studied. Listing of aquatic species for protection generally signals fundamental changes in the river's ability to provide suitable habitat.

All six case studies identified the Endangered Species Act as both an important legal signal of regime shift and an important driver of watershed to basin-scale self-organization to identify better solutions. Prior to development, the Columbia River supported spawning runs for large populations of Pacific salmon and steelhead, which provided economic, subsistence and spiritual importance to Indigenous peoples. Development has contributed to a precipitous decline in salmon populations, leading to listing of numerous populations under the US Endangered Species Act. Many of the same listed species occur in the Klamath River (Chaffin, Craig, et al., 2014). Anadromous fisheries on the Columbia and Klamath Rivers are maintained through federal, state and tribal hatchery programs. Currently at least 20 species in the Everglades are listed and receive protection, as are several bird species in the Platte, and fish and other aquatic-reliant species in the Middle Rio Grande (USFWS, ESA website). A regime shift from viable to endangered populations, and the legal protection afforded to these vulnerable species has been at the center of ongoing and incipient efforts to reconcile ecosystem function with developed river systems. In the Anacostia and the Everglades the US Clean Water Act is equally important in signaling potential regime shift and driving efforts aimed at reconciling ecosystem function with managed rivers. The next section more fully explores the role of governance and institutions in the observed social-ecological system dynamics, focusing on adaptive governance.

3 Adaptive Governance: The Emergent and Intentional Attributes

Before considering the emergence of adaptive governance in the North American case studies, it is useful to turn to the broader literature to situate these observations in the changes in governance emerging across western democracies. Beginning in the 1980s, public sector reform that resulted in an increased role for private actors in the delivery of public services and policymaking gave rise to a new area of literature on "governance" and "new governance" (Bevir, 2009), including in the environmental sector (Karkkainen, 2004; Lockwood, Davidson, Curtis, Stratford, & Griffith, 2010). "In its most general form 'governance' refers to 'the construction of social orders, social coordination, or social practices' through governmental rule, private or market activity, and includes emergent networks between government and society" (Bevir, 2009, p. 1). While initial reform in this area focused on a reduction in government involvement through increased use of markets and private networks, a return to the importance of government oversight and involvement has been driven in part by new external problems including terrorism and climate change, and in part by concerns with private corruption, democratic accountability, legitimacy, and equity (Bevir, 2009). The term "joined-up governance" arose to reflect governmental management, regulation, and facilitation of markets and networks (Bevir, 2009).

In parallel with scholarship on governance, resilience scholars began to observe an emergent form of governance as an alternative (or complement) to regulation and markets that seemed particularly suited to landscape-scale environmental management in the face of change and uncertainty. They labeled it "adaptive governance" (Chaffin, Gosnell, & Cosens, 2014; Dietz, Ostrom, & Stern, 2003; Folke et al., 2005). Empirical observation of the emergent attributes of adaptive governance, including adaptive water governance, reveal three categories:

1. **Problem-based scale** Emergence occurs at the problem-based scale. This is a corollary to the fact that adaptive governance is generally triggered by a social or ecological disturbance that cannot be addressed by a single entity. In response, self-organization and network formation emerges across the problem space. Thus, in the environmental arena, adaptive governance tends to emerge at the bioregional scale (Chaffin, Gosnell, et al., 2014; Dietz et al., 2003; Folke et al., 2005).
2. **Polycentric** Existing management and regulation is often inadequate because the problem space involves multiple jurisdictions and sectors. Thus, the emergence must be polycentric to succeed. At the same time, polycentricity improves inclusion and legitimacy as well as integration of management across sectors that affect the same resource (Clarvis, Allan, & Hannah, 2014; Folke et al., 2005; Marshall, 2007; McGinnis, 1999).
3. **Collaborative** The inefficiency and shear impossibility of creating a new governmental entity at the scale of every problem dictates that collaboration will be necessary for adaptive governance to emerge and succeed. This aspect goes beyond mere networks across governmental levels and sectors to include those who live within, rely on and use the environmental landscape or resource in question. This ground-up aspect of emergence also improves legitimacy and tailoring to the local context through the use of local knowledge (Dietz et al., 2003; Folke et al., 2005; Huitema et al., 2009).

Non-law scholarship recognized the role of government and law as an outer and necessary boundary on emergent behavior (Dietz et al., 2003). The overlap of this scholarship with governance research also led to the recognition of the need for attributes of good governance – i.e. accountability, equity, and justice – to ensure legitimacy in democratic societies (Lebel et al., 2006). However, the importance of legal reform to allow the emergence of adaptive governance while also authorizing governmental participation and assurance of good governance in implementation did not receive attention until legal scholars entered the field (Cosens, 2010, 2013; DeCaro, Chaffin, Schlager, Garmestani, & Ruhl, 2017; Ebbesson & Hey, 2013; Garmestani, Allen, & Benson, 2013). The Adaptive Water Governance (AWG) Project actually formed to fill this gap (Cosens & Gunderson, 2018), and the recognition of the role of government in facilitating adaptive governance to improve the chances that response keeps pace with accelerating change is one of its primary contributions.

The growing demand on aging infrastructure, long-term consequences of loss of ecosystem services, and the accelerating change associated with population and climate has led to problems on each of the North American basins studied at the bioregional scale. Due to the connected nature of water resources, the bioregional scale in these cases follows watershed, catchment, and basin boundaries. Emergence of polycentric, networked governance through collaborative processes is occurring in each of the six basins (Table 2). In all six basins, the emergent governance regime crosses private and governmental entities.

The governmental (or intentional) attributes found to be necceary for the emergence of adaptive governance in the study basins fall into the following six categories (see Cosens et al., 2017 and 2018 for details):

1. **Governmental structure necessary to balances stability, flexibility, and innovation**. Society seeks stability from government. Flexibility necessary for adaptation to rapid change seemingly contradicts that goal. Yet rigid adherence to the status quo in the face of rapid change must certainly destabilize. The key is balance (Craig et al., 2017, 2018). Panarchy is a useful heuristic for complex systems and governance structure. It is a concept in resilience that recognizes the importance of the scale below and above a system of interest (Gunderson & Holling, 2002). It helps illustrate that nesting of small-scale innovation within large-scale stability provided by resources, knowledge and enforced standard setting may help in striking that balance. The role of law in establishing the structure of government and distribution of authority across that structure is thus the mechanism to achieve this balance.
2. **Governmental authority necessary to allow networked decision making across jurisdictions, sectors and through the involvement of private actors**

   Problems appropriate for adaptive governance rarely occur at the scale of a single governmental authority or entirely within a single sector. The authority to collaborate across sectors and jurisdictions as well as with private actors must be embedded in both the authority and practice of governmental agencies.
3. **Government assistance in building participatory capacity**

   Despite advances in the recognition of rights for marginalized populations, those with power have greater access to decision-making, and those without power have fewer resources – i.e. time, money, and knowledge. As noted by Bevir (2009) in his review of governance "[a]dvocates of more participatory democracy are often acutely aware that different citizens possess different resources for participating. Hence, they often attend carefully to process issues about who participates in what ways and under what circumstances. So, for example, they might advocate state support for under-represented groups" (p. 19). Particularly in the context of populations suffering from the legacy effects of past discrimination (in North American basins this includes Indigenous peoples in the Pacific North West and African Americans in the Anacostia basin), governmental assistance in capacity building is essential to equitable participation in adaptive governance.
4. **Governmental Authority and funding to use tools of incremental, adaptive, and participatory decision-making**

Table 2 Environmental enhancements and degradation resulting from water infrastructure and management development across six study basins in the US

Basin/ watershed (Reference)	SES development regime	Environmental issues arising from development regime	Reconciliation: engineered and biophysical	Reconciliation: governance
Anacostia River (Arnold et al., 2014)	Navigation flood control industrial and stormwater pollution disposal	Increase in impervious surfaces leading to increase in flooding Decline in water quality due to agriculture and urbanization fisheries collapse (due to water quality and barriers); wetland loss	Green infrastructure to slow down runoff	Formation of watershed level organizations networked to higher levels of government as well as networked governmental organizations across jurisdictional boundaries. Catalyzed by the CWA. Beginning to empower groups with a legacy of racial discrimination. Local restoration innovation nested within federal level standards. Legacy effects of urbanization and discrimination based on race and class limit options.
Columbia River (Cosens & Fremier, 2014)	Navigation Hydropower Irrigation Flood Control Hatcheries	Flow timing; Riverine discontinuity connectivity; floodplain connection (storage, habitat, water quality); wetland loss; fisheries declined/ land alteration	Habitat restoration; hatchery modernization; Beginning of dialogue on flow timing, longitudinal and floodplain re-connection	Formation of regional governmental entities by states and by tribes. Watershed organizations. Push for increased adaptive capacity and increased participation in new international treaty negotiation.
Everglades Basin (Gunderson et al., 2014)	Flood control/ Drainage for urban and agricultural sectors Water supply for agriculture, urban and Conservation Areas	Loss of landscape connectivity Water quality regime shifts Biodiversity losses, Endangered Species, Wildlife population declines	Restoration efforts	Federal Agencies (Interior, Defense and Agriculture), State of Florida, Water management districts (Operations and Water Quality). CERP (Comprehensive Everglades Restoration Program)–

(continued)

Table 2 (continued)

Basin/ watershed (Reference)	SES development regime	Environmental issues arising from development regime	Reconciliation: engineered and biophysical	Reconciliation: governance
Klamath River (Chaffin, Craig, et al., 2014)	Hydropower Irrigation Flood Control Wetland drainage for agriculture	Water quality and timing of flow; natural storage; longitudinal connectivity; decline in fisheries	Establishment of protected area (Wildlife Refuge/ wetland) Agreement to remove dams – not yet funded	Bottom-up collaborative process triggered by unacceptable outcomes and incomplete solutions provided by application of endangered species law and tribal water rights and the opportunity provided by dam relicensing. Process facilitated by federal government. Dam removal solution institutionalization uncertain.
Middle Rio Grande River (Benson et al., 2014)	Irrigation Urban water supply; Flood control	Longitudinal and lateral connectivity; flow timing and water quality; seed dispersal for riparian species	Limited. Endangered species act may be forcing water transfers to instream flow, but this requires willing sellers. Upland forests are transitioning to a new regime as a result of climate change. Some fuel reduction programs seeking to address this	Local government and NGO collaborating on a major watershed restoration/fuel reduction initiative in the Santa Fe region of the basin. Nothing at the basin scale.
Central Platte River (Birge et al., 2014)	Irrigation Flood control	Longitudinal and lateral connectivity; flow timing and water quality; wetland drainage; biodiversity loss	Platte River Recovery Implementation Program (PRRIP). The Program includes restoration of certain habitat and flows.	PRRIP triggered by implementation of the ESA. Federal level facilitation led to the basin-wide plan. The program will use an adaptive management approach.

For each basin, the development regime describes the social objectives that resulted in the hydrologic modifications. The next columns describe the environmental issues that arose from the development regime. The righthand columns describe how reconciliation is being sought in the physical and governance dimensions

Many emerging environmental problems have a degree of complexity that increases the level of uncertainty regarding both the problem and its solution, and yet doing nothing in the face of this uncertainty may itself have adverse consequences (Ansell & Gash, 2008).Thus management solutions have been developed that involve monitoring, learning and incremental adjustment (Holling, 1978; Gunderson & Light, 2006; Craig & Ruhl, 2014 on adaptive management; Arnold, 2010 on adaptive planning), as well as increased use of dialogue and local knowledge through resilience assessment (Stockholm Resilience Center, n.d.). Government resources to monitor the results of management and to act on the results through incremental adjustment are essential to use of these tools. In addition to the use of these tools focused on single loop learning, opportunities for double and triple loop learning (i.e. double loop learning: revisiting the framing of the problem and goals; triple loop learning: questioning the underlying beliefs and values) (Pahl-Wostl, 2009) are essential. Finally, participatory decision-making challenges the science-based approach of natural resource agencies. What decisions are appropriate for public partnership? How should those partnerships be managed to ensure equal access? These issues must be addressed in the laws governing the process of government.

5. **Governmental process and structure that assures legitimacy, accountability, equity and justice**

   The interaction of government with private actors disrupts the traditional lines of accountability through representative government in democratic governance (Bevir, 2009). The devolution of the locus of innovation and implementation to the problem-scale and the use of participation to contextualize solutions may lead to capture by special interests and corruption. One solution has its parallel in the balancing of stability and flexibility – i.e., maintain and enforce high-level standards and oversight (Craig et al., 2017). However, this structural solution may be necessary but remains inadequate. The twentieth century growth of bureaucratic environmental management gained its legitimacy by basing decisions on science (Esty, 2006). However, the degree of scientific uncertainty associated with complex systems not only leads to erosion of the trust in science, it means that their management will always have a values component. Science is not a democratic process for making tradeoffs involving values. The impetus behind the rules governing process, found in the U.S. Administrative Procedures Act is to assure legitimacy in actions by civil servants who are one-step removed from elected office (Esty, 2006; Cosens, 2010, 2013). These rules address the goals of good governance (a term originally coined by the World Bank (1992), but now taken up in the broader governance literature (Lebel et al., 2006)), by providing for transparency, public involvement and review. Adjusting these rules to address situations of more robust public participation in management and to assure rights of review of incremental decision-making without paralyzing management is essential to the adherence of adaptive governance to democratic values (Cosens, 2010, 2013).

6. **Institutionalization of solutions through law**

   The case studies confirmed the short attention span of society and its elected government in addressing crisis. Without adoption in law of solutions resulting from collaboration, there is a tendency to move on and a corresponding dissolution of support for the results. Both the resources and knowledge to implement solutions often require governmental action. In addition, governmental authority to participate in implementation requires identification of legal barriers and their removal as well as the authority necessary for participation (Chaffin, Craig, et al., 2014; Chaffin, Craig, & Gosnell, 2018).

The following paragraphs focus on the observations of both the emergent and intentional attributes necessary for adaptive governance in the North American basin assessments done by the AWG project (Cosens & Gunderson, 2018).

In each of the six basins studied, emergence of adaptive governance is occurring in response to the implementation of environmental laws. In the Anacostia watershed, the Clean Water Act provides both the hammer and the platform for the formation of watershed organizations. In the Columbia, Klamath, Everglades, and Central Platte, the Endangered Species Act provides one of the hammers moving emergence of adaptive governance forward. In these cases, the inadequacy of a fragmented response to species listing (as well as other legal issues fragmented across sectors) leads to attempts to find alternative and more holistic solutions. Each of the basins is experiencing pressure from climate change, but to date, climate change is the primary driving factor for collaborative efforts only in the Middle Rio Grande where significant bioregional transitions are already being felt (Benson et al., 2014, 2018).

Facilitation, resources, and the clear identification of standards (e.g., species recovery under the ESA, water quality standards under the CWA) from higher levels of government (generally federal) has played a role in each basin. The Middle Rio Grande is the watershed with the weakest emergent response and it may not be a coincidence that the driver in this basin is climate change, which lacks enforceable standards or US federal level response.

The authority to work across agency boundaries or jurisdictions is not always clear or utilized when present (Gosnell et al., 2017), and lack of clear authority can act as a barrier to watershed scale solutions. Nevertheless when utilized, as in the Klamath Basin, it leads to more comprehensive outcomes (Gosnell et al., 2017).

The importance of governmental assistance to build participatory capacity was most prevalent in the assessments of the Columbia, Klamath and Anacostia basins. The Columbia and the Native American Tribes who have inhabited its landscape since time immemorial provide a clear example of why rights must be accompanied by capacity building. Treaty rights to fish off-reservation "at all usual and accustomed places in common with citizens of the Territory" (Nez Perce Treaty, 1855) were tested in the 1960s and 1970s, and the resulting federal court case held that the Tribes were entitled to 50% of the harvest passing these locations (United States v. Washington, 383 F. Supp. 312, 1974). While this ruling was a major step in the recognition of rights, the Tribes would be unlikely to have the role they play today as co-managers of the Columbia River anadromous fish runs had funding not been available to build capacity. The Tribes formed a fisheries science and policy agency called the Columbia River Inter-Tribal Fish Commission (CRITFC, n.d.), now considered one of the most sophisticated management agencies in the basin.

While the emergent collaborative processes in response to change in each of these basins illustrate a level of adaptive capacity, only the Central Platte is implementing an adaptive management plan. Attempts to do so in the Columbia River Basin (Lee, 1993, 1999; Lee & Lawrence, 1986; Volkman & McConnaha, 1993) and the Everglades (Gunderson et al., 2014, 2018) failed (although the use of adaptive management is again under discussion in the renegotiation of the Columbia River Treaty (British Columbia, 2019). Change in power blocked implementation in the Columbia (Blumm, 2002; McConnaha & Paquet, 1996), and litigation tied up implementation in the Everglades (Gunderson et al., 2014, 2018). In these instances, it is possible that the exercise of power and the use of the judicial system are symptoms of failure in legitimacy, accountability, equity and justice. A lack of finality in implementation of policies that affect investment (e.g. hydropower in the Columbia and agriculture in the Everglades) require new approaches to legitimacy and accountability, and measured stability to provide a sufficient degree of flexibility without sacrificing the capacity to adjust over time (Craig & Ruhl, 2014; Craig et al., 2017, 2018).

Finally, both the Columbia and the Klamath await institutionalization of solutions arrived at through emergent adaptive governance in the Klamath basin and broadly participatory problem solving in the Columbia basin. This critical step emphasizes the need for knowledge and resources from higher levels of government to institutionalize bioregional or landscape scale solutions that seek to reconcile ecosystem function with the benefits of aging infrastructure.

4 Reconciliation, Resilience and Management Regimes

A key insight from the application of resilience and panarchy theory to these large, regional- scale case studies has been to provide a lens for reconceptualization of these basins as social-ecological systems allowing a more integrated understanding of their water management regimes. As described earlier, a regime consists of ecological, engineered and social structures that attempt to meet multiple social goals and outcomes. Reconciliation ecology has been defined as the "science of inventing, establishing, and maintaining new habitats to conserve species diversity in places where people live, work, and play" (Moyle 2013, p. 7). It recognizes that restoration of developed systems to pre-human conditions not only may be impossible, it is inconsistent with the fact that humans are now an integral component of all earth systems (Barnosky et al., 2017; Benson & Craig, 2017). While the choice of the specific goals of reconciliation and even the choice to pursue reconciliation in environmental management are normative, and reflect the exercise of power and agency, managing environmental systems to achieve those goals in the accelerating change that characterizes the Anthropocene (Steffen, Crutzen, & McNeill 2007; Steffen et al., 2011), requires an understanding of system properties and how systems change. Resilience theory from ecology describes the behavior of complex systems undergoing change (Folke, 2006; Gunderson & Holling, 2002; Holling, 1973; Walker & Salt, 2006).

The word “reconciliation,” as used in the context of this paper, expands beyond the ecological to the social, economic and legal dimensions of these systems. That is, it reflects the reality of management that must resolve or reconcile conflicts and issues brought about by trying to match multiple (often competing) resource demands and by the inherent complexity of managed resource systems for which there is no panacea (Ostrom et al., 2007).

The case studies provide insights into the multi-faceted nature of reconciliation (Table 2). Those facets include changes or proposed changes in the engineered and biophysical structures in these systems that are designed to help undo environmental regime shifts. In the Anacostia, water pollution is being addressed through polycentric institutions and state and federal clean water legislation. The effort aimed at watershed reconciliation as part of the Chesapeake Bay restoration, manifests in the development of green infrastructure to slow down and clean up runoff (Arnold et al., 2014). The Comprehensive Everglades Restoration Program, authorized in 2000, attempts to restore declining environmental indicators, such as wading bird nesting and endangered species, as well as support the water supply and flood control needs of millions of coastal residents. In the Klamath River Basin, conflict over water and fish management in the basin reached a stage of public protest in 2001. The continued role of law, in particular the Endangered Species Act and the assertion of Native American reserved water rights, ultimately served as the catalyst for the emergence of collaborative processes and local adaptive solutions (Chaffin, Craig, et al., 2014; Gosnell et al., 2017). While dam removal along the Klamath River has been proposed as part of the system rehabilitation, it has not yet been funded. Habitat restoration and hatchery modernization, are underway in the Columbia basin, and dialogues on flow modifications, fish passage and flood plain reconnections have begun (Cosens & Fremier, 2014). In August 2019, salmon were released in the upper Columbia River in Canada, a stretch of river blocked by dams for 80 years (Caudill, 2019). The Platte River Recovery Implementation involves habitat modifications and restoration within the river, to meet ESA goals, as well as proposed modifications in flow regimes (Birge et al., 2014).

5 Discussion and Conclusion

Resilience theory arising out of ecology, captures emergent properties of complex social-ecological systems as the result of their internal and cross-scale interactions and feedbacks, and their responses to disturbance (Gunderson, 2000; Holling, 1973). Holling recognized the emergent properties of ecosystems including the capacity to adapt through self-organization. His work gave rise to the understanding in ecology that “[r]esilience is the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks…" (Walker et al., 2004, p. 7).

Empirical research on system resilience focuses on the processes controlling interaction of system components, leaving study of the components to disciplinary approaches. It captures a set of interrelated concepts in addition to resilience that describe the abrupt and nonlinear behaviors observed in ecosystems (Gunderson & Pritchard, 2002). It focuses on the capacity of the system to return to its prior state following a disturbance; its capacity to adapt, or transform; and the degree to which that capacity is influenced by or sensitive to changes at smaller and larger scales, a concept referred to as panarchy (Gunderson & Holling, 2002). In addition, resilience theory helps make sense of non-linear behavior of complex systems in response to disturbance. It recognizes that systems may reorganize into alternative regimes or states in response to a disturbance that exceeds system resilience, and the stability of this new regime makes it more difficult for the system to return to its prior state (Gunderson & Holling, 2002; Holling, 1973; Walker et al., 2004; Walker & Salt, 2006).

The major water infrastructure built in developed countries in the middle part of the last century relied instead on engineered resilience – i.e. the focus on resistance to disturbance measured by return time to a static equilibrium (Folke, 2006; Holling, 1996; for an excellent review of the various disciplinary approaches to defining resilience, see Quinlan et al., 2016). While engineered resilience has provided considerable benefits to society in the form of flood control, navigation, hydropower and irrigation, it has come at the expense of ecosystem services, processes and structures (Holling, 1996; Walker & Salt, 2006). Importantly, built water infrastructure was designed under the assumption that disturbance would occur within the bounds of the historic record. In a climate change world, this is no longer an appropriate assumption (Interational Panel on Climate Change [IPCC], 2018; U.S. Global Change Research Program [USGCRP], 2018). Resilience theory highlights the fact that the capacity of systems to adapt is a major component in determining their sustainability or transformability in the face of change (Gunderson, 2000). Restoring ecosystem function is a key aspect of enhancing adaptive capacity. Managing resilience is critical to achieving reconciliation of systems transformed through engineering with ecosystem function.

Scholarship seeking to bridge resilience theory developed in reference to ecosystems with theories of change in social systems, has pointed out that resilience theory fails to address agency and power, nor does it capture normative goals such as sustainability, equity, and justice (Cote & Nightingale, 2012; Davidson, 2010; Lockie, 2016; Olsson, Jerneck, Thoren, Persson, & O'Byrne, 2015). This chapter adheres to the definitions of engineering and ecological resilience (*sensu* Holling, 1996) and frames the additional complexities of social systems including processes aimed at achieving normative goals of legitimacy, accountability, and attention to equity and justice through the lens of law and governance. In doing so, adaptive governance emerges as an approach suitable to managing resilience.

Adaptive governance emerges from collaborative processes triggered by social conflict or ecological crisis (Cosens & Gunderson, 2018; Dietz et al., 2003; Folke et al., 2005; Huitema et al., 2009). As used in this chapter, the term adaptive governance includes a range of governance strategies including collaborative governance and adaptive co-management (Chaffin, Gosnell, et al., 2014), and relies on the broader effort to consider adaptive governance of the commons (Dietz et al., 2003; Folke et al., 2005), as well as the literature addressing the specific application to adaptive water governance (e.g. Cosens & Gunderson, 2018; Huitema et al., 2009). The common ground among these terms is their use to describe processes that: emerge at the problem scale (often the landscape or bioregional scale in environmental problems); cross multiple jurisdictions and sectors; and involve participatory processes and incremental decision making that allow for contextualized solutions (Ansell & Gash, 2008; Brunner et al., 2005; Chaffin, Gosnell, et al., 2014; Dietz et al., 2003; Folke et al., 2005).

Adaptive governance is not a panacea for managing environmental problems. Instead, it is appropriate in situations of high complexity, including periods of rapid change (Folke et al., 2005); problems with high uncertainty or conflict surrounding problem definition, and the potential results of management actions (Ansell & Gash, 2008); and problems that require multiple jurisdictions and sectors to address them (Cosens, Gunderson, & Chaffin, 2018). It is a term used to describe a family of strategies for incremental, flexible and contextualized management of complex problems (Brunner et al., 2005). Adaptive governance does not require major legal reform, but does require new processes and strategies for management of complex problems. It functions best within and complementary to existing regulatory and governance systems when the complexity (including scale) of the problem exceeds the capacity of traditional approaches to regulation and management. Adaptive governance is particularly relevant in efforts to increase the adaptive capacity of major river systems through reconciliation of development with ecosystem function (Gunderson, Cosens, & Garmestani, 2016).

This chapter discussed the management of ecological and engineered regimes and resilience in the context of social-ecological systems. The assessment of six North American water basins as part of the Adaptive Water Governance (AWG) project led by the authors (Cosens & Gunderson, 2018) sought to develop an understanding of the tradeoffs between engineered and ecological resilience and the opportunities for their reconciliation. The project focused on adaptive water governance and what is missing from the current literature – i.e. the intentional authority; its distribution and its processes that governments require to assure the emergence of adaptive governance in complex situations, as well as its legitimacy; and its efficacy.

Assessment of North American water basins by the Adaptive Water Governance Project reveal the emergence of governance with the capacity to respond to change at the watershed and basin scale. This capacity to adapt is a key aspect of managing resilience. However, the assessment also reveals that adaptation, including reconciliation of development with ecosystem function is not occurring at a rate necessary to respond to accelerating change as the result of population and economic growth and climate change. Adaptive governance must be catalyzed through government acting under the authority of law. The legal reform necessary must act as a complement to the traditional roles of regulation and markets to allow contextualized response at the landscape scale.

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Multilevel Governance for Urban Water Resilience in Bengaluru and Cape Town

Johan Enqvist and Gina Ziervogel

Abstract The multifunctionality of water in social–ecological processes complicates its governance, especially in cities where heterogenous populations lead different lives and hold different values. This challenge can potentially be addressed by combining bottom-up and top-down approaches through multilevel governance. Drawing on research from two large, water-stressed cities in the rapidly urbanising global South, this chapter presents concrete examples of how this has been tried to various degrees of failure and success. First, formal authorities need to recognise local initiatives and organisations as legitimate stakeholders, in order to build trust in the process and create buy-in from relevant communities. Second, it is important to understand these communities: their internal differences and power struggles, various priorities and needs, in order to design policies that will be effective and fair. Third, multilevel collaborations entails shared burdens between actors with very different abilities and resources; this requires realistic expectations and considerable facilitation in order to identify innovative and sustainable solutions to the complex set of problems at hand. By linking conventional 'managerial' and grassroots 'user' perspectives, multilevel governance holds the potential to strengthen cities' resilience against the broad range of challenges stemming from the multifunctional nature of urban water.

1 Introduction

Water is fluid and integral to all life, not just in terms of its physical properties but also figuratively. This makes it essentially multifunctional, as it is central to daily household uses, sustains complex ecosystems, shapes weather dynamics, provides

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electricity for entire nations, and so on. Management and governance that seeks to promote water resilience thus needs to anticipate and respond to a myriad of different types of fast and slow changes, across levels from the global down to the individual.

Anthropogenic influence on social-ecological systems is arguably most visible in urban areas, where land-use has changed dramatically and intensive use of finite resources such as water creates tensions between human needs and protection of ecosystem integrity (Groffman et al., 2016; McDonald et al., 2011). Urban areas' need for water and other resources means that they are intimately embedded in other higher regional, national and international levels – both directly by consuming water needed elsewhere, and indirectly by importing produce and products that have required or polluted water in their manufacturing. These cross-level dependencies become more important given the rapid changes and growing global water crisis of the twenty-first century described in chapter "The Emergence of Water Resilience: An Introduction", making it increasingly urgent to find ways to effectively address them. While cities contribute to undermining sustainability, it is also important to recognise their potential contributions. For instance, urban landscapes are becoming more homogenous globally as cities converge around similar types of heavily altered habitats and controlled environmental parameters like temperature and light. Locally, however, cities often display higher biodiversity than surrounding landscapes, since indigenous flora and fauna is mixed with exotic species in the mosaic of altered and preserved patches in the landscape (Pickett et al., 2011). Knowledge about such social-ecological diversity can be a source of resilience in the face of regional water scarcity, if a wider range of species are present to support ecological response diversity (Colding, 2007; Elmqvist et al., 2003) and help preserve urban green cover and ecosystem services when the climate changes (Enqvist & Goodness, 2019; Goodness, 2018).

Cities face growing international calls from a continuum of actors – from intergovernmental bodies to social movements – for reducing urban inequality and poverty, strengthening resilience and making cities "climate smart" (McPhearson, Iwaniec, & Bai, 2017; United Nations Framework Convention on Climate Change [UNFCCC], 2019; World Wildlife Fund [WWF], 2019). As mentioned in chapter "The Emergence of Water Resilience: An Introduction", water is central to addressing these issues. However, promoting water resilience requires taking into account the different and often competing ideas that local people have about what forms of water supply, distribution, use and recycling are necessary, sustainable and desirable from social, economic and/or environmental perspectives. In other words, if cities are to become more resilient, the multiple functions that water performs to different stakeholders need to be acknowledged in the governance arrangements set up to address pressing as well as long-term issues.

Starting with the challenges of urban water's multifunctionality, this chapter examines the potential in strengthening the linkages between bottom-up and top-down approaches through multilevel governance. Cognisant of the range of alternative prefixes to governance in resilience literature that praises the potential of bottom-up approaches (i.e., polycentric, decentralised, cross-scale, adaptive, see chapter "The Emergence of Water Resilience: An Introduction"), we use 'multilevel governance' because our investigation is primarily focused on and limited to coordination across levels from the city to local. Rather than discussing different theoretical frameworks, our aim is to demonstrate and compare practical examples of how bottom-up alternatives can be relevant for improving governance of multifunctional urban water. This is particularly relevant in rapidly changing cities with populations that are highly diverse in terms of income, ethnicity, language and culture, for example. There is also a specific need for lessons and insights from cities in parts of the world where most urbanisation is expected in coming decades: sub-Saharan Africa and South Asia (Fragkias, Güneralp, Seto, & Goodness, 2013). From a theoretical perspective, there is a need to "generate new concepts and revise old theories" particularly in cities that have not traditionally been well resourced and/or where histories of colonisation have actively undermined contributions to theoretical developments (Bhan, 2019; Parnell & Robinson, 2017). The growing urban areas in the global South have their own characteristics, not always consistent but often including high levels of informality, and should be feeding their own lessons into theoretical understandings (McPhearson et al., 2016; Nagendra, 2018). Correcting these wrongs is a need that goes far beyond the scope of this chapter, but we hope to contribute to wider perspectives on southern urbanism.

To contribute to this, this chapter focuses on the governance of urban water, a natural resource that is particularly important to both the well-being of urban residents, city functioning and economic growth. We draw on insights from our own research in Bengaluru (formerly known as Bangalore), India, and Cape Town, South Africa; both cities that have attracted international media attention to the growing threat of urban water scarcity (BBC News, 2018; Bhasthi, 2017; Onishi & Sengupta, 2018) which according to hydrological models is a growing concern especially for cities in Asia and Africa (McDonald et al., 2011). As we describe in the following, Bengaluru and Cape Town are growing rapidly, largely due to immigration from the regions around them, and have considerable economic inequality as well as demographic diversity based on culture, ethnicity and race. This will serve as a basis for examining the potential of, obstacles to and limitations of bottom-up approaches, and at the end of the chapter, recommendations for how these can be more effectively linked.

2 Multifunctionality in Two Water-Stressed Cities

Bengaluru and Cape Town are both among the most populous and economically important metropoles in their respective countries. They share a British colonial past, and are relatively cosmopolitan and linked to global trade; Cape Town especially through tourism and agricultural exports, Bengaluru through its numerous call centres and IT companies supporting overseas businesses (Sudhira, Ramachandra, & Subrahmanya, 2007; Wilkinson, 2000). As growing economies, they attract significant numbers of immigrants from nearby rural areas as well as further away in southern Africa and south Asia, respectively.

Bengaluru, the ‘Silicon Valley of India’, is located inland in the semi-arid south which has historically depended on small dams storing monsoon rainwater to support agriculture. Since the 1970s, the city’s main water supply has been pumped uphill from the Cauvery river located 100 km south; meanwhile the dams that were previously maintained by farming communities have mostly fallen into disrepair, polluted or encroached by the expanding city (Enqvist, Tengö, & Boonstra, 2016; Nagendra, 2016). This expansion has been particularly rapid in recent years, increasing the population from 8.5 million in the 2011 census to over 12 million in 2017 (Sudhira et al., 2007; United Nations [UN], 2014; World Population Review, 2019). Despite costly infrastructure augmentations to keep up with growing water demand, many households are left with intermittent municipal supply, especially during the hot summer months. Millions of residents depend on private boreholes for access to groundwater, which means that the city’s neglected dams still play a role in watering its people – giving an advantage to those who have resources to pay for their own borehole, or at least buy water from the informal traders that fill tanker trucks illegally from remaining lakes and unmonitored boreholes (Lele et al., 2013; Sudhira & Nagendra, 2013). Depending on who you ask in what part of town, water bodies in Bengaluru can be seen as stinking cesspools, pristine habitats for birds and amphibians, sources of livelihood through fishing or clothes washing operations, pleasant scenery to enjoy while having a picnic, obstacles to profitable housing development, rainwater harvesting units for groundwater recharge, sources of devastating floods, or suitable for immersion of religious idols and offerings after Hindu ceremonies.

Cape Town, the ‘Mother City’ of South Africa, sits below the iconic Table Mountain where natural springs attracted Dutch settlers in the seventeenth century. This initiated centuries of varying levels of conflict over land and water, as the often violent expansion of European peoples gradually pushed different African groups either to subjugation or extinction (Brown & Magoba, 2009; Enqvist & Ziervogel, 2019). Today, the metropolitan area is home to around 4 million people and water is supplied from six dams in surrounding mountains; however, municipal service providers still struggle to erase the inequality left from the legacy of colonial and *apartheid* discrimination (Beck, Rodina, Luker, & Harris, 2016; Enqvist & Ziervogel, 2019). During 2017, rains far below the average sent Cape Town into the third year of a record-breaking drought (Wolski, 2018). Only through disaster declarations and massive efforts from municipal authorities, businesses and residents to reduce daily consumption to below 50 litres per person was the threat of ‘Day Zero’ avoided – this was to be the day when household water would be disconnected and residents would have to queue at public taps for 25 litre rations (Department of Water and Sanitation [DWS], 2018; Ziervogel, 2019b). The experience was in many ways a city-wide trauma; however, hundreds of thousands of Capetonians living in informal settlements already queue at taps for their water, and inferior infrastructure leave many areas historically designated for non-whites particularly vulnerable to seasonal flooding, sewerage blockages, and leaking pipes (Enqvist & Ziervogel, 2019). Water in Cape Town can signify anything from the memory of a looming disaster, to something requiring a daily inconvenience to acquire, to independence from an incompetent government through a private borehole, to a force that can physically destroy one's home, to a key variable in the Cape's unique endemic *fynbos* ecosystem, to a tool that the state uses to still control the lives of its most vulnerable citizens.

Both Bengaluru and Cape Town are shaped by distinct political geographies, not least in terms of safety from water. In the low-lying Cape Flats, seasonal flooding regularly impacts low-income households more often due to inadequate drainage and lower-quality houses. In Bengaluru, the least affluent often find space for shacks on dried-up lake beds, only to be exposed to flash floods during monsoon rains that previously drained through the network of lakes. The two cities also have somewhat similar future prospects in that they are both reaching limits to how much water their governments can provide: Bengaluru is pushing past its allocated share of Cauvery water, sparking tension with neighbouring states (Enqvist et al., 2016; Lele et al., 2013); meanwhile although Cape Town has no more feasible sites for additional dams, the city is exploring groundwater and desalination options, and its local government's attempts to collaborate with its national-level counterpart are sometimes impeded by party politics or limited capacity within the national-level water authorities (Enqvist & Ziervogel, 2019; Ziervogel, 2019b). However, there are also some positive signs. In Bengaluru, growing engagement from residents forming local trusts to protect lakes has led to formal partnerships with municipal counterparts, sharing management responsibilities for some water bodies (Luna, 2014; Nagendra & Ostrom, 2014). These 'lake groups' often emphasise a broader range of functions that need to be promoted, from groundwater recharge to healthy ecosystems to local livelihoods; furthermore, they have also shown a capacity to collaborate with each other to promote inter-lake connectivity across the fragmented landscape (Enqvist, Tengö, & Bodin, 2020; Murphy, Enqvist, & Tengö, 2019). In Cape Town where the immediate crisis is over, municipal authorities are scrambling to reinvent water governance and increase water resilience by promoting a 'whole-of-society' approach that seeks to build collaborations and trust between city government and the public (City of Cape Town, 2019b; see also Enqvist & Ziervogel, 2019). Given the historical legacy of poor service delivery and neglect of low-income areas, the city has tremendous hurdles to overcome. Fortunately, civil society is also active and organisations that have advocated for improved water services for years, such as the Western Cape Water Caucus, are mobilising to contribute to a process that will hopefully be more than just words.

For both cities, these changes represent critical challenges and a shift away from top-down versions of water governance where central public agencies and large-scale infrastructure technologies are the norm. The cases illustrate that water cannot be treated as one single thing, but that it in fact has multiple functions in across the different parts of the urban landscape. In the following, we will demonstrate the varied and sometimes conflicting uses and values associated with multifunctional water resources and waterbodies. This also means that one water crisis can carry different implications for different people, and finding long-term solutions to them depends on finding a way to work with that inherent complexity. This is critical for guaranteeing that water governance is both effective, i.e. serves intended functions, and fair, i.e. caters to all stakeholders' needs including those of future generations. A central question that guides our investigation is this: Given the difficulty of grasping the full, multifaceted nature of water, what opportunities are there for sustainable urban water governance?

This question will be examined from the perspective of multilevel governance, engaging with government responses, at the city level, through non-governmental and civil society organisations, to local residents at the neighbourhood level. Within this space there are both bottom-up and top-down responses to environmental risk as well as efforts to co-produce and co-create responses across different levels. We seek to understand the multiple opportunities and barriers to exerting influence over the course of events, and to examine the relationship between different 'local' interpretations of resilience and what the concept might mean for a city as a whole. In some of the examples we describe, actors are able to change trajectories and draw on their resources and connections to do so. In other instances, despite what looks like favourable conditions, trajectories are hard to change and an undesirable situation prevails.

3 How Multilevel Governance Can Help

3.1 The Curse of Top-Down Versus Bottom-Up

Water governance refers to the political, social, economic, and administrative systems that control formal and informal decision-making regarding development and management of water resources (Batchelor, 2009; Woodhouse & Muller, 2017). It often rests on normative and sometimes controversial ideas of what is a desirable outcome, where for instance goals like transparency and human rights can stand in conflict with demand for cost recovery and liberalized markets (Batchelor, 2009; Harris, McKenzie, Rodina, Shah, & Wilson, 2016). What is often referred to as 'conventional' water governance includes interventions steered from the top down, focusing on water supply. For some time, many international bodies and national agencies have increasingly advocated for bottom-up alternatives that involve local people and groups, more on the demand side of water use (Batchelor, 2009; Smith, 2008). Top-down approaches relying on a central decision-makers have been criticised for neglecting other actors which inhibits the ability to see weaknesses in the intervention; in cases where no such central entity exists, a top-down model is arguably ineffective (Sabatier, 1986). Top-down failures have also been identified in developing countries, that have often experienced failures when states have been unable to cater for all citizens' water needs, like during public budget cuts to meet international lenders' demands. Paired with high hopes around local community capacities, this fed into an increasingly optimistic discourse around bottom-up alternatives and devolution of water management responsibilities (Smith, 2008).

However, there is also reason for caution. Bottom-up water management initiatives have been criticized for failing to create meaningful, actual participation (tokenism); for assuming that communities are easily identifiable, homogenous and have shared goals; for overestimating local capacity; and for lacking the skill and capacity to facilitate effective participation (Smith, 2008; Ziervogel et al., 2019). Following these criticisms, Smith (2008) presents four recommendations to ensure that bottom-up approaches lead to more effective and sustainable water management strategies:

1. Genuine commitment: avoid tokenism, seek meaningful collaboration and inclusion.
2. Understand communities: be clear about diversity, complexity and dynamics.
3. Realistic expectations: communities have constraints and cannot do everything.
4. Adequate facilitation: participation requires professional and tailored design.

Below, we use these recommendations to structure insights about partnerships that *combine* top-down and bottom-up management, as opposed to choosing one over the other (Sabatier, 1986; Smith, 2008). Different versions of such partnerships are described elsewhere in this volume (Chaps. "The Sustainable Groundwater Management Act (SGMA)—California's Prescription for Common Challenges of Groundwater Governance", "Reconfiguring Water Governance for Resilient Social-Ecological Systems in South America", and "Adaptive Governance in North American Water Systems: A Legal Perspective on Resilience and Reconciliation"); however, we argue that they can be particularly useful to promote multilevel governance that addresses the multifunctional nature of urban water, since multiple actors working jointly are likely to identify a broader range of issues as well as solutions related to water governance. Furthermore, we respond to a critical need to provide lessons about how such partnerships might work in global South cities, where residents often rely on informal as well as formal actors, infrastructure and politics for the provision of basic services like water management (Kooy, 2014; Kudva, 2009; Millington, 2018). The paper draws primarily on our own research in Bengaluru and Cape Town, which has used a range of often mixed methods often with particular emphasis on in-depth qualitative understanding of the problems at hand (Enqvist et al., n.d., 2020, 2016; Enqvist & Goodness, 2019; Enqvist & van Oyen, n.d.; Enqvist & Ziervogel, 2019; Matikinca et al., 2020; Murphy et al., n.d., 2019; Ziervogel, 2019a, 2019b; Ziervogel et al., 2019).

3.1.1 Genuine Commitment

Recognizing non-conventional actors such as local residents and NGOs as important contributors to partnerships can help to create buy-in across levels. By demonstrating that participatory governance arrangements also translate to real devolution of decision-making powers, the process can gain legitimacy and more support on the ground. Our research on lake groups in Bengaluru (Enqvist et al., 2020, 2016) has revealed a marked difference in attitudes from municipal officials once the first partnership was formalised in 2010:

> I don't think [the municipality] was so approachable before. It was very risky. We couldn't talk to the [local political representative]. I think a lot of gutsy people have stepped in. […] Before, filing [a request for public records] was considered risky – people would be targeted. (Member of lake group formed in 2011)

> In India, […] very often [the] bureaucracy of a civil service and the [local groups] are at conflict. […] But at least [on] this [lake] issue, […] there is no conflict. Whatever they want, we also want the same thing. (Chief Conservator at Greater Bangalore Municipal Corporation)

Once it became clear that officials were more open to civic engagement, the number of lake groups started growing 2–3 times faster than before 2010. Importantly, the groups' strategies also shifted and became less confrontational: while more than half of the pre-2010 groups had resorted to legal action against authorities, none of the newer ones initiated such combative measures (Enqvist et al., 2020).

Reaching this point can be challenging and requires trust in the process as well as both sides showing good faith. In Bengaluru, this often ended up being a function of interpersonal relationships between individuals seeking to reimagine lake management models. Some government branches were still seen as uncooperative which holds back improvement for certain lakes and issues such as groundwater management.

Like many South African cities, Cape Town struggles with a legacy of systematic top-down discrimination of many communities, including but not limited to provision of water services (Enqvist & Ziervogel, 2019). While formally everyone now has the same rights, many still struggle to even know who to contact when faced with a problem – especially in previously underserved neighbourhoods. These problems have contributed to a lack of trust between public agencies and the people they are meant to serve, as some assume that no help will ever come:

> A water [management] device was installed [in my house] about a year ago. Recently I received a water bill totalling more than R16,000. Accepting the device came with an assurance that my water arrears would be scrapped. A week ago my water was cut, [the City] demanding an immediate payment of about R10,000 before reconnection. I tried unsuccessfully to engage with council, saying I don't have that kind of money. They promised to look into matter. Until today, still nothing. (Story 81 of 311 shared to Western Cape Water Caucus interviewer (Enqvist et al., n.d.)

This eroding trust is problematic and undermines multilevel governance. Without the groundwork of establishing functioning collaborations before the recent water crisis, it was hard to quickly mobilise support for the city's response during the drought (Ziervogel, 2019b).

Such crises can add further stress to sensitive processes and relationships between government representatives and civic organisations. For instance, when one of the authors joined fellow community representatives to observe the City's trial run of a water distribution centre at a local sports field, organisers were hesitant to allow the group's presence fearing that information would be disseminated with the intent to discredit the City's work. The possibility of working together to design the water distribution had to be advocated strongly by the local residents. However, there has also been examples of the crisis helping to dissolve other hurdles that initially caused problems. As expressed by one member of staff at the City's Water Demand Management department, collaboration within the municipality improved in some ways:

> It was a fantastic time to work here, as we got cooperation from all departments and were able to get things done that we weren't able to do before. (quoted in Ziervogel, 2019b, p. 14)

This suggests that otherwise rigid institutions can sometimes be pushed to change by external shocks. This was also demonstrated in the City of Cape Town's engagement with the business sector, which during the beginning of the water crisis was frustrated by the lack of information about what was happening. As the drought progressed, significant progress was made in building relationships, networks and sharing of information between businesses and the City government. These networks, that would not have developed independently in the same way, now have the potential to be used in other ways. In Bengaluru, the coincidence of a looming water supply crisis for water sources outside the city, and redrawing of metropolitan boundaries to include several unspoilt water bodies, similarly created a window of opportunity to take control by reforming water governance institutions to better coordinate between regional to neighbourhood levels (Enqvist et al., 2016).

3.1.2 Understand Communities

Bottom-up engagement has a critical role to play in valuing the everyday realities of urban life and enabling multilevel water governance to function in a context of urban heterogeneity and conflicting interests, especially within communities themselves (Ziervogel, 2019a). An ongoing study using Q-methodology (Enqvist & van Oyen, n.d.) shows that fairness in Cape Town's water tariffs means different things depending on what residents you ask. Some considered it most fair that everyone pays for all the water they use, at the same rate; others interpreted fairness as meaning that high-volume users pay a higher per-litre rate to subsidise free water for the poorest; yet another group expressed that fairness should entail public participation in tariff setting and water conservation policies. In Bengaluru, people's motivation to participate in lake restorations stems from a range of meanings that places evoke, such as childhood memories, cultural pride, awe of ecological processes, or influenced by their own stewardship involvement (Murphy et al., 2019). This is critical for helping to push for lake designs and access that cater to different lake uses, which includes fishing, clothes washing, birdwatching as well as depending on it to recharge local boreholes (Murphy et al., n.d.; Unnikrishnan & Nagendra, 2014). Paying attention to temporal changes in people's relation to water bodies reveals considerable differences, as shown in two respondents' description of the same lake:

> I used to farm when the lake was big and had gardens. I used to feel happy. Wherever I went, I'd be like 'No, I have to go back to the lake!' But now I don't have interest, I don't even want to see it. Now it's small, it's dirty. (Villager born by the lake 55 years earlier)

> When I came the lake was dry. I was a part of the revival team from a dump yard to a lake overflowing. This whole year I saw the water level rising from the bed. So now I love coming here, working here, helping out in whatever way possible. (Lake group member living near the lake for 3 years)

Shedding light on the breadth of different lived experiences that exist in a city is particularly important during and immediately after crises such as Cape Town's recent drought. In its wake, municipal authorities have developed a new Water Strategy as well as Resilience Strategy (City of Cape Town, 2019a, 2019b), to take a 'whole-of-society' approach to help adapt to and address challenges such as climate change, rapid urban growth and persistent poverty. While many water-related challenges in low-income areas are well-known (leaking pipes, blocked and overflowing sewers, faulty meters, seasonal flooding, etc.), gaining access to a deeper understanding of people's lived realities in such communities can be difficult in a city still defined by significant spatial segregation. When services fail, many resort to temporary fixes that risk further entrenching their disassociation from the City:

> The plumber was trying to by-pass the [water] meter box but he couldn't do it properly so it started leaking. But the household couldn't go to [the] City as it was illegal, so they don't know where to go to get it fixed now. (Water Caucus member describing a neighbour's situation, Personal communication, 2019-08-29)

To try and address these sorts of problems, we collaborated with a community-based organisation called the Western Cape Water Caucus in a transdisciplinary research project that has collected stories from 311 residents in six different townships and informal settlements of Cape Town (Enqvist et al., n.d.). Using a tool called SenseMaker™ (Lynam & Fletcher, 2015), we developed the interview questions together with the organisation and trained members who live in the study areas to collect the stories using smartphone apps. This approach makes it possible to access people's lived experiences, and includes a way for respondents to signify the meaning of their story – as opposed to the interviewer or researcher interpreting it. Importantly, research officers from the municipal Water and Sanitation Department have participated in this process as observers, hoping to learn about ways to gather knowledge about citizens' lived reality beyond what is captured through their existing customer satisfaction surveys.

3.1.3 Shared Burdens

This section reflects on Smith's third and fourth points (Realistic expectations and Adequate facilitation), which are both part of the challenge of how to share burdens and responsibilities in multilevel partnerships. The local level can typically not be expected to have adequate resources for all tasks, nor is that level ideal for addressing all problems. Furthermore, complementing bottom-up activities with top-down ones introduces new needs for active facilitation and coordination. There are growing calls for ways to measure and assess what effect bottom-up approaches might have on governance. In Bengaluru, we have tested lake groups' ability to improve 'fit' between management institutions and the hydrological connectivity between lakes, finding that while groups have a positive impact they still rely to some extent on forging partnerships with actors at higher, municipal levels (Enqvist et al., 2020).

Bottom-up initiatives may have limited abilities to implement extensive institutional change but can play a key role in early envisioning processes and model examples of success through pilot projects. This is especially true for identifying more socially desirable and sustainable development pathways. In Bengaluru, where water governance has been locked in an unsustainable trajectory of increased reliance on a single source outside the city, bottom-up lake restorations have contributed a concrete articulation of an alternative vision of water use, that acknowledges the reality of widespread dependence on the city's groundwater and therefore also its lakes (Enqvist et al., 2016). Active scenario-based planning has been used to bring together government officials, civic groups and others in thinking about the city's future water security (The Indian Institute for Human Settlements [IIHS], 2018). In Cape Town, during the City's pilot testing of a public 'point of distribution' in preparation for Day Zero in 2018, a local civic association presented their own work to help map vulnerable residents such as elders or single parents – as well as a plan for how to provide street-level assistance to those that would not be able to access water at such points. Further, the SenseMaker project (described above) attempts to systematically record people's lived experiences in order to develop knowledge both about 'what is' and 'what should be', as well as 'how to make it happen'.

Some of the limitations of community-based groups can be compensated for by shifting to a different level: forming umbrella organisations, to coordinate efforts and engage as equals with higher-level actors. By acting as bridging organisations and knowledge holders, such entities can help translate setbacks and failures from local-level experiments into learning opportunities for the broader communities. In Bengaluru, an international NGO lent critical support through funding and expertise when the first lake group negotiated its partnership with municipal authorities (Luna, 2014). Subsequently, the Save Bangalore Lakes Trust has emerged as an umbrella initiative by lake groups to host workshops where groups can learn from each other, and coordinate advocacy with public officials for policy change at the city level, beyond individual lakes (Enqvist et al., 2016). This can also favour inclusivity, by fostering relationships between municipal government and neighbourhood-level intermediaries who live in the areas affected by an issue and understand the local context well (Ziervogel, 2019a). In Cape Town, the Water Caucus is itself an effort by members from different low-income communities to act jointly to learn about and address water issues at city and state level; it is also linked to chapters in other provinces as well as the national South African Water Caucus (Environmental Monitoring Group, n.d.).

Multilevel governance shifts the roles and responsibilities of city governments that partner with grassroots organisations. This can be a difficult process. Ten years ago in Cape Town, an experiment around trying to co-produce potential solutions to reduce flood risk between city officials and residents in a low-income area effectively failed (Ziervogel, Waddell, Smit, & Taylor, 2016). Expert facilitators helped to conceptualise the process, recognising that power dynamics were likely to be tricky, but City actors were worried about how they would maintain control and were concerned about safety issues. As a result, instead of a full co-production process a shorter, limited process of engagement was undertaken.

In both our case studies, it has been critical for bottom-up groups to access information on who is responsible for water and what is being done within the respective bureaucracies. Bengalurean lake groups often made use of the Right To Information Act to find out what department to hold responsible for deteriorating lake conditions (Enqvist et al., 2016); in Cape Town, municipal authorities went through a steep learning curve and eventually made data about dam levels, water use and supply augmentation plans available (Ziervogel, 2019b). Sharing information about the increasing likelihood of Day Zero turned out to be a more effective demand management tool than increasing water tariffs, but inconsistencies in and politicised messages undermined trust and collaboration with many community organisations (Matikinca et al., 2020; Ziervogel, 2019b).

3.2 Summary: Multilevel Partnerships in the Global South

As argued in Cape Town's recent Water Strategy (City of Cape Town, 2019b), addressing urban water needs is likely to be a whole-of-society endeavour – especially in sub-Saharan Africa and south Asia where urbanisation and climate change are likely to have more severe impacts than elsewhere (Fragkias et al., 2013; McDonald et al., 2011). The insights presented above are therefore particularly valuable because they help build knowledge about how multilevel governance can work in two cities located in these regions. While they do not represent all of the urban South, the cases provide several empirical examples to further nuance how Smith's four recommendations can be interpreted and applied in the real world – especially facing complex challenges like water governance. Genuine commitment to partnerships with bottom-up initiatives is particularly important to demonstrate in contexts where participatory approaches have previously been unreliable or non-existent (as is the case in both our examples). Understanding communities is a greater challenge when these communities are changing rapidly due to urbanisation and growing partially in unplanned settlements, where informal authority figures and powerholders emerge with great influence over people's daily lives. It is worth repeating that 'communities' are also highly heterogeneous and one group of local residents do not speak for all. Our Cape Town case demonstrates examples of different informal settlement residents working jointly to communicate grievances to the municipality; in Bengaluru on the other hand, some lake groups view informal settlements as a threat to their view of a fully protected and restored lake. The tension between realistic expectations of communities and adequate facilitation of collaborations requires special attention in societies defined by a greater distance between rich and poor, between well- and poorly educated, and where the fundamental task of water governance involves greater challenges than those where urban development is easier to manage.

4 Discussion: What Are the Implications?

In light of an emerging new water paradigm around water resilience, our chapter draws attention to water's multiple and fluid roles especially in urban settings. As illustrated in Sect. 2. in the cases of Bengaluru and Cape Town, water plays different roles in people's lives and few people see the full range of uses it can have. Consequently, water resilience also has a multitude of definitions depending on place, level of analysis, and subjective values. This has important implications for finding pathways forward, not least in light of calls for more interventionist approaches to sustainability expressed through ideas like 'urban tinkering' (Elmqvist et al., 2018) and 'ecology *for* cities' where "urban ecologists, designers, planners, engineers, residents and other are actively pursuing more sustainable futures" (Childers et al., 2015, p. 3778–9).

Resilience thinking is integral to navigating change in such interventions, in two major ways: in order to strengthen resilience of systems that are in a desirable condition, and, importantly, to weaken resilience of systems that one wishes to change towards a more favourable situation (Walker & Salt, 2006). For example, the formal water supply system in Bengaluru is undesirable from the perspective of those whom it does not provide reliable services or who wish to preserve traditional water sources – but its reliance on a single source and single technology also undermines its resilience to fluctuating rainfall and growing water demand. The innovations explored by lake groups in Bengaluru, based on multiple different understanding of water, has the potential to spread up from the neighbourhood level to help adjust the broader, city-level development trajectory (Enqvist et al., 2016). Similarly, the drought in Cape Town prompted thinking and action around securing more diverse sources of water as well as a recognition of the need for more adaptive, collaborative approaches to managing water. The city government managed to adapt in some ways, exhibiting more system resilience than before the crisis. Still, it was constrained in other ways, often because of rigidity stemming from national-level stalling and confusion of mandates which undermined potential governance innovations to deal with the crisis.

The examples presented in this chapter illustrate how working with water's multifunctionality serves resilience better than conventional attempts to control and focus on a single function at a time. Similar thoughts have been expressed in writings about cities as following 'composite trajectories', made up of multiple development pathways running in parallel (Parnell & Robinson, 2017). Cape Town both seeks a fair way to provide water services for all residents, and simultaneously implement tariffs to fund this. Bengaluru's breakneck population growth encroaches on its lakes, but growing needs for water supply and disposal also requires that lakes ecosystems are protected. These pathways all shape how the cities develop, and therefore all need to be considered to effectively navigate pressing problems. Multilevel governance that brings in complementary bottom-up perspectives promotes participation and learning, and therefore stands a better chance of finding sustainable management approaches (Ziervogel, 2019a). Focusing on 'approaches' rather than 'solutions' or 'outcomes' is particularly important in times of change, whether driven by climate change, urbanisation or other factors. A better understanding of the complexity and heterogeneity of a system also makes it easier to question the status quo and explore different ways to adapt and transform. Building such understanding requires partnerships, which cannot be formed by just one type of stakeholder. A full roadmap of all those that could play a part in this remains outside the scope of our chapter; instead, we have focused on demonstrating how partnerships require genuine commitment, good understanding of communities, and clear and realistic expectations on the responsibilities of the parties involved. Critically, for this to help strengthen multilevel governance there is a need for accountability mechanisms, a topic beyond the scope of this chapter. Below, however, we outline some starting points and further research needs regarding the role of three key actors: city governments, residents, and researchers.

City governments need to take residents and community organisations seriously and make good on ambitions to promote collaborative approaches in water governance (e.g. Cape Town's Water Strategy). This includes municipal, provincial and national branches of government operating at city level. They are important gatekeepers for gaining access to information and resources through formalised collaborations (e.g. Bengaluru's lake partnerships), but they also need to acknowledge the challenges associated with participatory approaches, and the importance of facilitation in enabling this. This typically requires an understanding of the needs and vulnerabilities as well as capacity and knowledge held by local residents. We see a need for research about how to facilitate multilevel partnerships, especially in low-trust environments where both authorities and communities have limited resources, and in cases where more powerful vested interests in the private sector might already have established communication and collaboration with city officials. From a resilience perspective, the benefits and constraints brought by more or less urgent water crises can be useful entry points for such studies.

Residents need to draw on their strengths, which include a better presence to monitor on-the-ground problems and solutions, and a power in numbers (if a cause rallies enough enthusiasm). Since they are typically the direct beneficiaries of water resources – or the victims of water-related disasters – residents have a different perspective and sometimes more immediate experience than those who merely manage urban water. In the right partnerships, this can be a critical asset for setting up management arrangements that align well with local social and ecological processes. Residents-based organisations often need to balance work to push authorities to do their job with seeking self-empowerment to take over some responsibilities from those authorities. While the latter can give greater influence over outcomes, it requires more effort and might therefore not be a tenable option for all groups, especially not in the long term. Here, inspirational 'success stories' and information about best practices can make a bit difference, showing the importance of umbrella organisations or NGOs at a higher level. Documenting such practices, as well as developing tools to assess the impact of bottom-up approaches – without idealising communities as a panacea for all management problems – remains an important study area particularly in the urban South.

Researchers increasingly need to play a part in multilevel governance, beyond their traditional role as knowledge producers. In addition to helping to fill the research gaps described above, their 'third party' position can also allow them to broker and even facilitate collaborations between governments and residents that might struggle to establish working relationships on their own (Hamann & April, 2013). Scholarly expertise on the hydrology of, engineering around and ecology intertwined with water can be an important resource to complement local knowledge, in particular if there is a need to translate information gathered through bottom-up initiatives into reports and briefs that decision-makers will pay attention to. If there is room for prolonged engagement, this can also involve activities to empower citizens to carry out studies and engage in participatory processes to promote their goals. Importantly, researchers should acknowledge that this pushes the boundaries of conventional academic work and need to be wary of their own positionality and subjectivity, and the power relations they are part of and engage with.

5 Conclusion

To conclude, we argue that governance for urban water resilience requires an understanding of how actors at the city level versus neighbourhood level respond to water-related problems based on their preferences, and how trade-offs, negotiations and conflicts play out when preferences are misaligned. Understanding such multilevel dynamics involves both recognising the current state of affairs, discerning future desirable outcomes, and the transformational knowledge and capacity of how to realise that outcome.

Knowledge about water challenges and how to enable responses to them cannot effectively be held by a single actor or even organisation, given the conditions that define a growing number of cities globally. As we have shown, multilevel governance that draws on the respective strengths of bottom-up and top-down approaches holds important potential for working with water's multifunctionality. It is not a panacea, but by building on pre-existing formal and informal governance institutions it can prove to be a more realistic option in cities where there are not enough resources, capacity or time develop entirely new ones. This approach to multilevel governance may also prove to be more adaptable and in tune with urban dwellers' water needs in current times of rapid change and increasing climate-related uncertainty.

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Facing Change: Understanding Transitions of River Basin Policies Over Time

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Abstract The purpose of this chapter is to sythesise current knowledge and understanding of river basin management and governance in the context of water resilience. In particular, the chapter explores the politics and socio-ecological conditions that enabled or challenged policy responses to deal with major changes occurring in a basin using the case studies of the Mekong, Colorado and Murray-Darling rivers. The chapter focuses on the way institutions evolve to address uncertainties and the role of stakeholders and their use of knowledge and learning. It is shown that river basin development occurs over time with varying opportunities for institutionalising water resources management and governance across these three basins. It is found that water resilience is contested by multiple stakeholders, highlighting the power laden ways in which institutions evolve. Insights from the cases inform policy lessons on water resilience that emphasise scrutiny on an institution's suitability to support continual processes of deliberation and stakeholder engagement.

1 Introduction

Over a decade ago, a list of the world's top ten endangered rivers was published (Wong, Williams, Pittock, Collier, & Schelle, 2007). These rivers were threatened by a range of water quality, quantity and ecosystem problems, triggered by infrastructure development, water over-extraction, pollution, climate change, invasive species and over-fishing. A quick review of the state of these rivers now would seem

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to indicate that these problems are persisting and still challenging to resolve. In the years since, it has become clear that river basin management needs to deal with many factors of uncertainty particularly from anthropogenic change of climate: "stationarity is dead" (Milly et al., 2008). As chapter "The Emergence of Water Resilience: An Introduction" indicated, these rivers face a plurality of water crises. With a critical need to meet socio-ecological changes, it would seem that water resilience is being tested in these basins. The stakes are high for river basin management all the more.

In conditions of non-stationarity and instability, the traditional responses to river basin development may no longer be effective. The different paradigms of water management, ranging from diffuse low water use across a basin, intensive centralised water use, to water use seeking efficiency have hitherto prompted various policy approaches (Allan, 2003). However, the drivers and contexts of these paradigms are now much more complex with non-stationarity. Recalling the discussions highlighted in the introductory chapter, a shift in water paradigm has been advocated and increasingly applied in various water contexts. This reality reflects the need for policy approaches to address a range of compounding hydrological, climatic, socio-economic, and political factors that influence water use and the ecosystem of the river basin.

The purpose of this chapter is to synthesise current knowledge and understanding of river basin management and governance in the context of water resilience. The chapter explores the politics and socio-ecological conditions that have enabled or challenged policy responses. We focus on the Mekong and Murray-Darling Rivers (which were named in the top ten endangered river list mentioned above) as well as the Colorado River, a river long touted as being a 'closed basin' where no further water can be reallocated for alternative use (Falkenmark & Molden, 2008). The chapter is particularly interested in the way institutions have evolved to address uncertainties and whose knowledge and learning underpin them. As the analysis will show, while the three basins have had varying progress in transitioning from one water management paradigm to another, all basins face the problems of adapting institutions to a diverse set of water use and interests of stakeholders. Moreover, the case studies demonstrate common challenges of strengthening institutions to support deliberation on the priorities of water use and to cope with uncertainty. Water resilience in these cases are highly contested and not a given.

The rest of the chapter is organised as follows. First, the chapter reviews the different characteristics of water management paradigms. As paradigms evolve, stakeholders change, as with their roles, resources and means of input to decision-making. In particular, knowledge as a resource and social learning as a means to influence decision-making are highlighted to examine water resilience. Second, case studies are used to examine three unique river basins and their trajectory of river basin development. As large river systems significant to their respective regions, the Mekong, Colorado and the Murray-Darling have gone through major changes of water use over time. Key events such as droughts and introduction of specific policy tools such as legislation and agreements have shaped these changes, as well as the cumulative effects of water use over time and space. The analysis draws on the authors' in-depth experiences in the basin, both as scientists and participant observers: collectively we have over four decades of working in these three river basins. The analysis is a synthesis of insights gleaned through our own research and experience of policy and management in the basins which combine documentary analysis, interviews, stakeholder meetings, conference attendance as well as surveys and data analyses of monitoring data of biodiversity and ecosystems. Therefore, quantitative and qualitative data have informed our understanding. Furthermore, the analysis in this chapter presents an interdisciplinary approach to understanding the complex challenges in each basin. This approach enables our examination of various dimensions of water resilience through multiple disciplinary lenses so as to cut across the changes apparent in the physical environment as well as the socio-economic and political environment. The synoptic view of the paradigm shifts gives insight to the way uncertainty has been dealt with, and in many cases continues to challenge governance responses. Third, the chapter discusses the contested nature of water resilience and how responding to uncertainty is a power-imbued engagement of multiple stakeholders. Fourth, the chapter concludes with insights on why water resilience is not necessarily a fixed or objective notion.

2 Managing Change

It has been argued that river basins tend to follow a trajectory of intensified water use, which then tapers off in varying degrees due to management responses, physical limits of water availability or a combination of both (Allan, 2003) (see Fig. 1). The most intense period of water use is often referred as the hydraulic mission where there are centralised efforts to withdraw, store and divert water. This paradigm of water use relies on infrastructure to aid water access and allocation. Society ordering nature through engineering and investments becomes evident. However, the limitations of this approach gradually become evident with over-abstraction and negative impacts to ecosystems. The subsequent paradigm of reflexive modernity involves exploring efficiency measures (such as recycling water or water saving technology) or utilising integrated water resources management (IWRM) to seek balance between principles of efficiency, equity and protecting ecosystems (Allan, 2003). Over time, river basin organisations are not only charged to organise water abstraction but also allocation to a range of uses, including water for the environment. In addition, it is argued that the subsequent paradigm includes alternative governance mechanisms to the hitherto top-down, centralised approach (Allan, 2003). Epistemic communities, multi-stakeholder groups, water user associations and other forms of networks are established to facilitate mediating competing water uses. A feature of these later paradigms is how and when public participation is used in decision-making. As the case studies will show, moving on from the hydraulic mission also means asking questions about how to meet water use for maintaining small-scale subsistence farming as well as large-scale water abstraction for economic development from a national perspective.

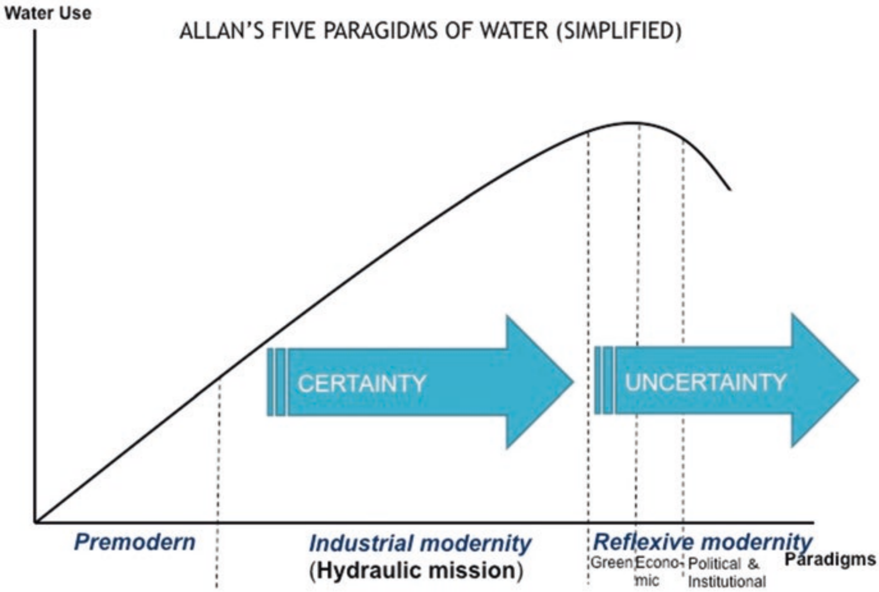

Fig. 1 Water management paradigms. (Adapted from Allan, 2003: 10)

In conditions of non-stationarity characterised by uncertainty, water use may be constrained, making it difficult to maintain existing practices. Moreover, resilience is brought into sharp focus when extensive water abstraction and low river flows compounds dealing with drought or other climatic changes. Consequently, it may become difficult to fulfil the potential of the hydraulic mission or may require pre-emptive use of efficiency measures to satisfy water demands. This means that paradigms of water management may not unfold in a sequential manner as depicted by the conceptual model above. In fact, empirical insight demonstrates that basins can continue its hydraulic mission while at the same time implementing water efficiency measures, as in the example of Thailand (Mirumachi, 2012). The transition of paradigms is not clear-cut and measures to achieve water resilience may be taken up, either as a strategic decision or a reaction to events such as droughts and flooding. Importantly, although conditions of uncertainty may challenge existing decision-making procedures, new water management mechanisms are not necessarily easier to introduce or be integrated into the existing institutional structure. Path dependency has been one explanation for this resistance to changing existing water allocation policies and mechanisms. In other words, long established practices of water management and vested interests of key stakeholders may hinder changes, despite the pressing need advocated by others (Mirumachi, 2015).

It is therefore important to analyse the kinds stakeholders involved and their vested interested in maintaining existing policy decisions or altering them. Particularly with the global uptake of IWRM, it has been widely recognised that water governance involves not only central government agencies traditionally tasked with water resources management, but also related line agencies, civil societies, local communities and businesses. These stakeholders have varying capacities and resources to influence decision-making. In particular, it has been argued that the use of knowledge is influenced by the institutional set-up, politics and cultural context in which these stakeholders operate (Kirchhoff, Lemos, & Engle, 2013). Put differently, what kind of knowledge is used and how is not a given but mediated through various factors. Here, science is (merely) one input into decision-making in this multi-stakeholder process (Armitage et al., 2015). Different kinds of expert and non-expert knowledge are mobilised by different stakeholders to advance claims and influence decision-making. Knowledge is also used by boundary organisations that translate and transfer information between policy and scientific research.

Along with knowledge, learning demonstrates how stakeholders react in the face of uncertainty. In the scholarship of resilience, learning can be defined as "a change in knowledge, skills or attitudes, that may result in changes in behavior, or even institutions" (de Kraker, 2017, p. 100). In the context of managing water, the literature on adaptive management indicates that the interaction of different stakeholders and their knowledges allow for opportunities of learning (Baird, Plummer, Haug, & Armitage, 2014; Gerlak, Heikkila, Smolinski, Huitema, & Armitage, 2018; Huitema et al., 2009). Learning may be established through experiments, such as those on environmental flows (Kingsford, Biggs, & Pollard, 2011). The effects might be better coping with change and uncertainty or increased trust between stakeholders and improved chances at cooperation (de Kraker, 2017). However, it has been pointed out that while learning has been lauded as important, the goals, means and implications of such learning are left undefined when put into practice (Armitage & Plummer, 2008). The scholarship of resilience as a whole has proven to be limited in its understanding of purposeful, functional use of social learning as a means of enhancing resilience. It has been found that despite the attention towards learning, there are only 10 empirically grounded studies that provide insight to the conditions to actual resilience. These studies found that learning contributes to building resilience at the local level where there is a semblance of power differentials between actors and that these actors have a stake in problem solving. This condition is not necessarily easily translated to larger scales. Intentionally creating opportunities for social learning, especially at national levels are challenging, requiring bridging organisations and policy entrepreneurs to help take advantage of networks and limited chances to bring about change (de Kraker, 2017). As such, particularly in the context of seeking water resilience, questioning who is included and excluded in the process of learning reveals the power relations between stakeholders (ibid). Learning, and more broadly, the governance of water resources entail contestation over values (Ingram, 2011). Such contestation is often intractable but tradeoffs are made when decisions prioritise certain water use over others. Through an analysis of learning, it is possible to better understand the deliberation and justification of these tradeoffs and how uncertainty is addressed.

3 Mekong River Basin Case Study

The Mekong river drains a catchment area of 795,000 km^2 with the upstream basin shared between China and Myanmar, and the lower basin stretching across Laos, Thailand, Cambodia and Vietnam (Mekong River Commission [MRC], 2011). The lower basin contributes the majority of annual flow (80%) and is a significant source of livelihoods for the 64.8 million people living in this region (Koponen, Paiboonvorachat, & Munoz, 2017). The river flowing over 4300 km has been the site for transportation, water abstraction and diversion for irrigation, fisheries development and, more recently, dam construction for hydropower (see Fig. 2). The river is also rich in biodiversity, including 850 fish species and those relying on a unique wet season flood pulse for their habitat (Orr, Pittock, Chapagain, & Dumaresq, 2012). Urbanisation of the basin countries also contributes to changes in domestic and industrial water use.

A set of comprehensive reports and surveys in the 1950s mark the start of transboundary river basin planning for the lower Mekong region comprised of Laos, Thailand, Cambodia and Vietnam. Commissioned by these governments, the studies focused on projects for flood control, irrigation and hydropower development. Prior to this period, while there had been some attention to transboundary water development in the region, they concerned navigation (Chi, 1997). Consequently, these studies indicate plans for active development of the hydraulic mission where opportunities to expand water use were sought. The premise of water use was to accelerate socio-economic development of the region (Mirumachi, 2015). A multilateral river basin organisation, the Committee for the Coordination of Investigations in the Lower Mekong Basin, or the Mekong Committee (MC), was established in 1957. Their Indicative Basin Plan Report published in 1970 set out ambitious engineering projects including dams on the mainstream as well as water management of the flood pulse lake, Tonle Sap (MC, 1970).

However, despite the accumulation of scientific studies and institutional development of the river basin organisation, it was only in the 1990s that hydropower development started in earnest. Until then, piecemeal hydropower and irrigation development occurred in the form of national projects, the majority in Thailand. The only multilateral infrastructure project was the Nam Ngum dam in Laos, delivering hydropower to Thailand. Consequently, hydropower development was negligible during the 1950s to 1980s. There was a general lack of engagement when basin countries' relationships broke down in the 1970 due to Cold War tensions and regional instability. Furthermore, by the late 1970s, with the Khmer Rouge regime in power, Cambodia had withdrawn from multilateral dialogue over the Mekong and from international politics. Thus, the river basin organisation could only be revived in the form of the Interim Mekong Committee, limiting opportunities for basin-wide projects.

The institutionalisation of river development projects brought to light intractable issues of water use rules and principles necessary for the expansion of the hydraulic mission at the basin level. While there was overall an appetite for dam

Fig. 2 Map of the Mekong River basin (http://www.mrcmekong.org/highlights/the-study-on-sustainable-management-and-development-of-the-mekong-river-including-impacts-of-mainstream-hydropower-projects/)

construction by the lower basin states, downstream impacts were a major concern. The use of mainstream waters directly affected water flow, which is a key aspect of river management for a region with monsoon rainfall and high seasonal variation of water availability. Whether binding rules would apply to mainstream use was debated and Thailand, with the largest prospect of utilising water resources, was opposed to restrictive decision-making processes put into place within the MC (Mirumachi, 2015).

It can be said that a second phase of the hydraulic mission began in the 1990s with large-scale hydropower development, though not led by the lower basin states and instead unilaterally by upstream China. The first mainstream dam, the Manwan dam, was commissioned in 1992 in Yunnan province. Subsequently, five further dams were built over the next two decades. This hydraulic mission is different from this first phase in that there were IWRM practices also implemented by the Mekong River Commission (MRC) and within basin countries. The MRC programmes use IWRM as a way to organise multiple sectors relating to the river and its resources. In addition, national governments have also taken up IWRM in their water policies and planning efforts. This creates a situation where while coordinated development is advocated, accelerated dam building is occurring, with seven dams currently being planned further upstream of these completed dams (see International Rivers, 2013). In addition, construction of the first mainstream dam in the lower basin, Xayaburi dam in Laos, began in 2012. Laos has since actively put forward projects with the Don Sahong dam commencing construction in 2016 and a further two projects, Pak Beng and Pak Lay proposed. It is reported that as of 2018, 150 hydropower dams are under construction, commissioned or planned with a capacity of 15 MW and above (Geheb & Suhardiman, 2019). This network of dams creates an energy market where hydropower is exported as a commodity within the region (Middleton & Allouche, 2016).

This major phase of damming the river reflects resource abstraction in the Mekong region. This abstraction is buttressed by geopolitical drivers of China extending its reach on economic opportunities abroad, with investment in large-scale infrastructure (Geheb & Suhardiman, 2019). However, there are several challenging uncertainties associated with this hydraulic mission. First, coping to ecological and socio-economic impacts from these dams is uncertain. Scenario analysis and strategic impact assessments of mainstream dam projects consistently point to significant impacts on hydrology, sediment transfers, and biodiversity loss (Mekong River Commission [MRC], 2017; International Centre for Environmental Management [ICEM], 2010). To address these challenges, developers have suggested engineering solutions that would mitigate impacts to fish migration and diversity and resolve issues of sediment. However, these means of mitigation are not congruent with experiences and views of local communities that will be most affected. These technical approaches do not take into consideration the practices of fishermen or those relying on river bank farming, who adapt to seasonal change of the physical environment. Nevertheless, these solutions are dominant in state-led development plans that aim to increase the hydropower capacity of the basin (Fox & Sneddon, 2019).

Second, the hydraulic mission may not provide as much opportunities for hydropower as anticipated. In the future, actual demand may be less than planned due to overestimation or as a result of changing energy sources (Geheb & Suhardiman, 2019). Third, there is uncertainty over whether the institutional set up of the basin can address transboundary water governance challenges. While this river basin organisation has deliberated over the lower mainstream dams through their Procedures for Notification, Prior Consultation and Agreement (PNPCA), it has been critiqued that this process has been ineffective in qualitatively changing the decision-making, particularly in taking up downstream concerns (Yasuda, 2015). Moreover, as with previous arrangements of the river basin organisation, tributary projects continue to be left off the table for multilateral discussion, thereby evading scrutiny. China, previously an 'observer' to the MRC, established the Lancang Mekong Cooperation framework in 2015. While much larger in scope with water issues being only one part of this economic cooperation initiative, questions arise on how and to what extent decision-making through this new platform may shape river basin development.

As the above depicts, the management of the river has been largely led by lower basin governments, as well as external agencies such as the UN and donor organisations supporting the river basin organisation. The interests of these stakeholders are generally uniform: development of the river resources. The phase of dam development opens up this stakeholder landscape to Chinese state-owned enterprises (SOEs), thereby shifting the modes of financing away from reliance on these donor agencies and onto established international financial institutions. However, the top-down nature of decision-making over these dams has nevertheless held out and the policies of transboundary water allocation are rather resilient. Non-state actors and civil society groups are increasingly rallying their concerns but the means for public participation at the MRC fora are critiqued as being inadequate (Yasuda, 2015). Legally binding rules over mainstream water use have remained un-established, thus requiring negotiations and consultations per project. This situation risks appropriate identification of cumulative ecological and socio-economic impacts across the basin, rendering efforts to mitigate piecemeal.

Infrastructure has become a fixed feature of the basin, as in many basins with intensive efforts at water abstraction. Moreover, it is underpinned by a modernistic meta-narrative shared by the Mekong countries that positions energy development as the cornerstone to transition into a more prosperous future (Geheb & Suhardiman, 2019). Tightly intertwined with this notion of modernity is the privileging of technological approaches and technical knowledge. Modernistic futures see technology as unlocking opportunities to break away from past under-development. In the context of dams, engineering and technical knowledge is prioritised over socioecological knowledge or observed, experiential knowledge of local communities. This means that not only the knowledge around the impacts of dams may be limited but also skewed, leaving out crucial aspects of livelihood changes that matter most to those relying on the river basin.

Here, Lebel, Grothmann, and Siebenhünter (2010) pointed out that the MRC in fact "learnt how to *do* public participation [emphasis in original]" by recognising the role of civil society networks which challenged technical insights (p. 347). This represents an engagement in a social learning process designed to adapt to issues of water allocation and river development challenges. Network building and knowledge sharing within civil society and with the governmental sector, campaigning and publication of reports utilising socioecological knowledge have raised awareness to some degree such that the MRC cannot make themselves immune to a social learning process. Multiple social learning processes also enabled fisheries and livelihoods to be valued and included as part of the debate on infrastructure development and to be incorporated joint assessments. However, the social learning process has fallen short of fully fleshing out alternative ideas, knowledges and inputs. Within the MRC, there was a tendency to de-politicise decision-making and controversies were not discussed widely enough. This meant a missed opportunity in seeking wider public acceptance for infrastructure development as well as giving due consideration to fairness of these interventions (Lebel et al., 2010).

This outcome can be explained in part by the role of knowledge. Fox and Sneddon (2019) argued that engineering knowledge maintains superiority over ecological or social science; furthermore, it works to de-legitimise and render local knowledge less useful. This elitist decision-making securely puts into place path dependency on the hydraulic mission, focusing on water abstraction. The phase of dam development installs infrastructure at high capital cost. The transformation of the basin through these engineering efforts further limits alternative options because of these costs (Mirumachi, 2015). While strategic plans developed by the MRC highlight the importance of public participation, it has been reported that the engagement of civil society is further required, not to mention challenges of fatigue, if not disenchantment of public participation. This inadvertently enables the top-down decision-making features of the governments implementing water management (Budryte, Heldt, & Denecke, 2018). Un-doing dams thus become highly difficult, entrenching the priority given to modernistic ideals and engineering knowledge.

4 Colorado River Basin Case Study

The Colorado River is essential to the social, economic, and environmental vitality of the western United States. From pre-history to today, the success of human settlements in this region has depended on a society's ability to capture, store, transport, and use water to support life in this semi-arid environment. The Colorado River runs 2330 km from its headwaters in the Rocky Mountains to the delta in Mexico, draining an expansive watershed of 637,137 km^2. The basin includes portions of the states of Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming. The river provides domestic water supply for more than 30 million people, including residents in major metropolitan areas of Denver (2.88 million), Las Vegas (2.20 million), Los Angeles (13.1 million), and Phoenix (4.73 million) (U.S. Bureau of Reclamation [USBOR], 2012). The Colorado River water irrigates 5.5 million acres of land, contributing to national food security, regional agricultural economies, and rural community identity. Hydropower plants on the river provide more than 4200 megawatts of renewable, low-carbon electricity. The river supports diverse natural ecosystems, wildlife refuges, and national parks, including Grand Canyon National Park. The Colorado is also integral to the history, culture, religion, and economies of nearly two dozen Native American tribal communities. A set of interacting social, economic, technological, and environmental factors, however, is increasingly stressing water availability for humans and nature in the basin, creating complex risks to current and future river basin resilience (National Research Council, 2007).

The development trajectory of Colorado River basin management and governance is characterised by episodes of significant conflict as well as periods of innovative collaboration, catalysed by interactions among dynamic networks of interested stakeholders (Fleck, 2016; Sullivan, White, Larson, & Wutich, 2017). The origins of contemporary governance can be traced to the early 1900s, when the active development of the of the hydraulic mission of the basin began in earnest. Key events in the industrial modernization of the Colorado include the National Reclamation Act of 1902, which created the United States Reclamation Service (later known as the U.S. Bureau of Reclamation), the 1922 Colorado River Compact, and The Boulder Canyon Act of 1928. In this era, mounting social and political pressure to "reclaim" the western United States strengthened the position of interested stakeholders, especially agriculturalists, who supported and benefited from rapid and widespread expansion of centralised water infrastructure to abstract, store, and divert water for irrigation. In a speech to a joint session of Congress in 1902, U.S. President Theodore Roosevelt committed to "the sound and steady development of the West" (Roosevelt, 1902, para. 56). This vision manifested on the landscape through federally-supported dams for water storage, flood control, hydropower, and irrigation. Notable milestones include the completion of Roosevelt Dam on the Salt River in Arizona in 1911, Hoover Dam on the Arizona-Nevada border in 1936, and Glen Canyon Dam in Arizona 1966. These hydropower dams represent major societal investments in water infrastructure that set the basin on a path of increasing development, population growth, and subsequent environmental degradation, especially impacting the delta.

The extensive damming of the Colorado, along with the associated water allocation and water use rules, were institutionalised over several decades through a patchwork of laws, court decisions, and regulations that are collectively known as "The Law of the River" (see USBOR, 2019b). These rules guide the allocation and distribution of water between seven U.S. states and Mexico, who regulate the end-uses. The keystone agreement is The Colorado River Compact of 1922, which established upper and lower basin boundaries (see Fig. 3) and allocated 7.5 million acre-feet (MAF) per year to each basin.

The original agreement did not include a transboundary compact with Mexico, but this oversight was addressed in 1944 by the Mexican Water Treaty, which allocated another 1.5 MAF of Colorado River water annually to Mexico. These allocations illustrate a political decision-making process negotiated among powerful stakeholders with certain groups, most notably Native American tribes, who had been marginalised and also largely excluded from consideration (see Fig. 4). Although the U.S. Supreme Court established in *Winters v. United States* in 1908 that water rights on Native American reservations belong to the tribe at the time of reservation establishment, the adjudication and allocation of these Native American rights remains a contentious and unsettled issue (see Colorado Research Group, 2016).

Fig. 3 Map of the Colorado River basin showing the upper and lower basin (https://www.usbr.gov/dcp/)

The modernist vision of the industrial Colorado reflects an understanding of a stationary climate and certainty of scientific knowledge about the reliability of natural river flows. Notably, institutional rules required that the upper basin would deliver an average minimum of 7.5 MAF per year to the lower basin, regardless of natural inflow. Thus, the allocation rules include a promise of a specific volume of

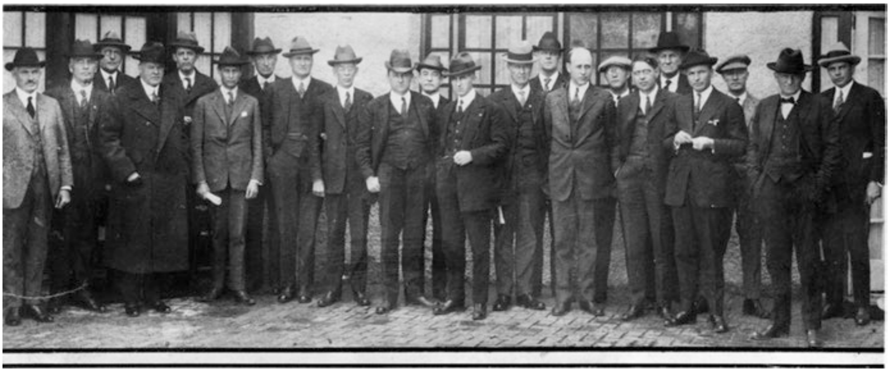

Fig. 4 Federal and state representatives to the Colorado River Compact Commission in Santa Fe, New Mexico including Arthur P. Davis, Director of Reclamation Service and Herbert Hoover, then Secretary of Commerce, November 24, 1922 (US Bureau of Reclamation 2017 https://www.flickr.com/photos/usbr/33491081615/in/photolist-cc4jmC-T2uxKD/)

water to the lower basin states, rather than a proportion of the natural flow. Unfortunately, the original allocation decisions were unintentionally formulated using overestimates of natural flow, based on an historically high-flow period (Castle et al., 2014). Indeed, quantitative reconstruction of natural flows from tree ring studies suggests that the allocations were determined based on observations in the early 1920s of what were the highest sustained flows in four hundred years (Stockton & Jacoby, 1976). While the rules obligate about 16.5 MAF annually, the basin-wide long-term historical natural flow on the river averaged just 14.8 MAF over the twentieth century (1906–2018). Even more troubling, the recent running average (1988–2015) was just 13.2 MAF, showing the effects of a two-decade long drought and the impacts of climate change (USBOR, 2018). However, because of the massive storage capacity of the major reservoirs of Lake Powell and Lake Mead (>50 MAF), water withdrawals in the Colorado river basin (excluding inter-basin transfers) averaged about 17 MAF per year from 1985–2010. Irrigation accounted for most total withdrawals in the basin, excluding instream use for hydroelectric power and inter-basin transfers, averaging 85% from 1985–2010 (Maupin, Ivahnenko, & Bruce, 2018).

In recent decades, water resilience and security of the Colorado River system has been in question. High agricultural demand, rapid population growth and urbanisation, land use changes, legacy effects of historical policies, and aging infrastructure are major pressing issues (Gober, 2018; Sullivan et al., 2017). On top of these social stressors, environmental factors have also increased risks. Since 2000, the region has experienced the most extreme drought in 100 years and among the worst in the last 1200 years, causing water levels in the major reservoirs to fall to historic lows and depleting groundwater reserves (Udall & Overpeck, 2017; USBOR, 2018). According to the Fourth U.S. National Climate Assessment the Southwest will by mid-century see higher annual mean temperatures, more frequent and severe droughts, more extreme heat, more variable precipitation, and greater wildfire risks, among other impacts (Gonzalez et al., 2018). It is unclear whether the Colorado River basin management and governance regimes can adapt rapidly enough to deal with the risks to water resilience in this era of deep uncertainty and climate change (Gober, 2013, 2018). Critics say that the traditional regimes suffer from path dependence, sunk costs, technological lock-in, and a lack of incentives to consider transformational changes necessary to address the myriad risks (Lienert, Monstadt, & Truffer, 2006).

Indeed, recent history indicates that the social and environmental risks have influenced the dominant socio-technical water governance regime. This disruption may have created windows of opportunity for networks of stakeholders to introduce innovations and transformational changes, which could precipitate a sustainability transition (Loorbach, Frantzeskaki, & Avelino, 2017; Sullivan et al., 2017; Sullivan, White, & Hanemann, 2019). Since about 2000, many stakeholders in the basin states have recognised the urgent need to adapt current policies, but progress has been halting. Growing concern over rapidly declining reservoir levels in Lake Mead and Lake Powell prompted leaders in the affected states and the U.S. Bureau of Reclamation to negotiate a policy to spell out actions to be taken in the event of a water shortage. Those negotiations culminated in a 2007 agreement establishing rules for coordinated operations of Lake Powell and Lake Mead and setting rules for water curtailments in the event of an official declaration of shortage on the river (USBOR, 2007). Along with these new institutional rules, networks of stakeholders developed a series of conservation policies and innovative programs. For example, the Bureau of Reclamation partnered with the Central Arizona Water Conservation District, The Metropolitan Water District of Southern California, the Southern Nevada Water Authority, and Denver Water to fund the Conservation Pilot System Program. This program funded a variety of locally-developed, voluntary conservation concepts created by stakeholders, including environmental, municipal and industrial, and agricultural groups, to reduce water demand and mitigate effects of drought. Despite these efforts, the reservoirs continued to decline, and risks increase, until stakeholders recognised that the 2007 agreement, which was designed to guide basin management until 2026, would not be effective in managing risks to water security.

In the face of social and environmental uncertainties, as well as shifting paradigms in basin governance and management and evolving public attitudes, Colorado River basin stakeholders entered a complex and sometimes contentious process, which ultimately culminated in the Colorado River Drought Contingency Plans (USBOR, 2019a). Collaborative governance efforts in the initial phases of the policy process leading to the Drought Contingency Plans (DCP) (2016–2018) suffered from barriers such as retreat from urgency, distrust between stakeholders, short-term thinking, lack of transparency, and lack of inclusive process (Sullivan et al., 2019). As environmental conditions continued to worsen, and the U.S. Bureau of Reclamation applied immense political pressure on stakeholders in lower basin states to reach a deal or risk federal government intervention, stakeholders relaunched negotiations and ultimately came to agreement. In the final negotiations, key players included state government agencies, cities, agriculturalists, and, notably, Arizona Native American tribes, who emerged as the powerful dealmakers. Critically, the DCPs did not address several key issues directly, most notably climate change adaptation and the overallocation that was written into the rules in the early 1900s. However, the process represents a turning point in the basin governance and management toward a more collaborative and inclusive water governance process and gives stakeholders a new framework moving forward.

5 Murray-Darling Basin Case Study

The Murray-Darling Basin in southeastern Australia extends across four of Australia's states (Queensland, New South Wales, Victoria, and South Australia) and includes the Australian Capital Territory (see Fig. 5). There are two major rivers, the River Murray and the Darling River, each with their own tributaries (Leblanc,

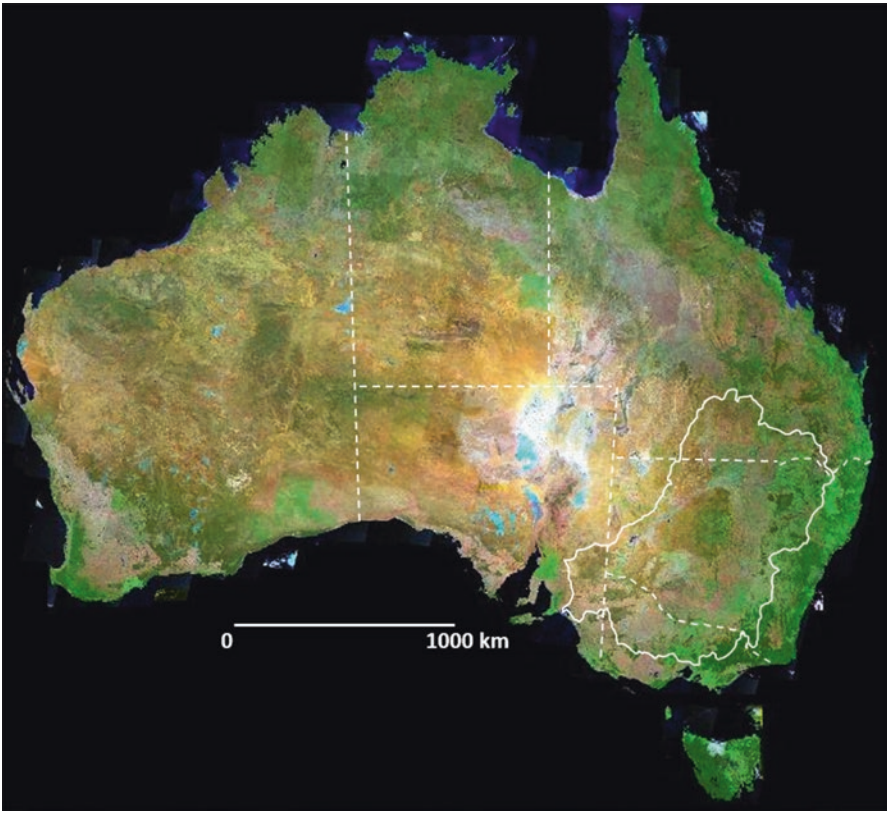

Fig. 5 Map of the Murray Darling Basin (solid line) in the southeast of the continent, with state borders (dashed lines) (author's own)

Tweed, Van Dijk, & Timbal, 2012). At 1.06×10^6 km^2, the Murray-Darling Basin occupies about one seventh of the continent, with river flows primarily driven by precipitation from the Great Dividing Range in the east of the continent. Tributary rivers typically flow into large floodplain wetlands (e.g. Macquarie Marshes, Great Cumbung Swamp) with about 4.5 million ha of wetlands in their catchments (Kingsford et al., 2004), including lakes, swamps and floodplains of which 16 are Ramsar-listed wetlands (Pittock & Finlayson, 2011). Eventually, the River Murray and Darling River join to flow southwest, reaching the sea through a system of lakes, lagoons and an estuary (Kingsford et al., 2011).

The rivers and wetlands of the Murray-Darling Basin (see Fig. 6) are rich in resources, providing for Aboriginal groups for millennia in the form of fish, caught in sophisticated traps (Humphries, 2007), with those on the Darling River at Brewarrina considered possibly the oldest human construction still functioning (Taylor, Moggridge, & Poelina, 2016). In the 1800s, the early European explorers (e.g. Charles Sturt) used the rivers to navigate to the inland of the continent. Soon afterwards, the Murray-Darling became the trade route for goods (e.g. wool) from the inland to the mouth of River Murray, south of Adelaide. The twentieth century was a period of considerable water resource development in the form of building large dams. This hydraulic mission focused on utilising the water in the upper reaches of the catchments, starting with Burrinjuck Dam on the Murrumbidgee River, the major tributary to the River Murray. There was then a significant investment by governments in large dams, particularly in the River Murray tributary but then extending into the Darling River tributaries, throughout the 1950–1970s (Kingsford, Walker, et al., 2011; Leblanc et al., 2012). Particularly iconic of this hydraulic mission phase is the Snowy Mountains Hydroelectricity Scheme, built in the late 1960s, establishing a series of large storages which regulated the southern tributary rivers (Tumut and Murrumbidgee Rivers) and once diverted 99% of the

Fig. 6 Tributaries of the Murray Darling Basin (author's own)

east flowing Snowy River as an interbasin transfer into the Murray-Darling Basin, before some river restoration (Erskine, Terrazzolo, & Warner, 1999).

As a result of this period of intensive infrastructure development, the Murray-Darling Basin now has largest storage capacity of any of Australia's river basins. This allows the diversion of most water of any river basin in Australia (Kingsford, 2000); total capacity of major storages now exceeds annual flow by about 40% (Goss, 2003). In addition, there has been considerable development of large private dams, particularly along the Darling River and its tributaries primarily to divert water for annual crops such as cotton (Australian Academy of Science, 2019; Kingsford, 2004). The role of water for agriculture is paramount because diverted water from the Murray-Darling Basin primarily supplies irrigation farming (>80%), producing much of country's agricultural commodities (rice (100%), cotton (93%), grapes (76%), oranges (100%)), worth AUD 7 billion (Murray-Darling Basin Authority [MDBA], 2016). River flows also supply major cities (Canberra, 356,600 people; Adelaide, 1.25 million people) and mining (35 mines, 1% of water use in 2004–2005) and many small rural towns.

The governance of the Murray-Darling Basin rivers has also evolved over time reflecting the demands and priorities of water use. Governance, legislation and policy for the Murray-Darling Basin rivers, as with all Australian rivers, was primarily determined by the four State Governments, originally established at Federation, under Australia's Constitution in 1901 (Connell, 2007). A cooperative management framework was first struck by the River Murray Waters Agreement in 1915 (Connell, 2007), when the States of Victoria, New South Wales and South Australia divided the flows of the River Murray, allowing development of the river. The River Murray Commission was established in 1917 followed by the Murray Darling Basin Commission (MDBC) (1986–2008). Major issues from river development including salinity and water quality degradation prompted the commission to manage water and other related natural resources under the principles of equity, efficiency and sustainability (Alexandra, 2019). However, each of the states separately established their water legislation which was primarily in effect until early in the 2000s. It was only then that a significant legislative review and renewal with modernisation of water legislation was introduced. The effects of this change emphasised the importance of the environment and sharing of waters, including with Traditional Owners. Much of this momentum came with the increasing environmental problems experienced by the river system, including the world's longest blue green algal bloom (Donnelly, Grace, & Hart, 1997) and the decline of wetland ecosystems (Kingsford & Thomas, 1995).

The sharing of river flows among users has been contested over time. First, the Murray-Darling Basin Cap was established in 1995 as a result of concerns and designed to halt further diversions at 1993/1994 levels of development in New South Wales, South Australia and Victoria and 1999/2000 levels of development in Queensland. A second major milestone was the *Water Act 2007* which allowed the Australian Government to take control and provide oversight on water use. This was precipitated by the Millennium Drought 2002–2009 which put further pressure on governments and their management of the Murray-Darling Basin Rivers. Along with the Act, an independent Murray-Darling Basin Authority, which replaced the MDBC, was charged with developing a Murray-Darling Basin Plan which included a restoration initiative for the river of more than AUD 13 billion. River plans remained the responsibility of the States but they were to be guided by the objectives of the Murray-Darling Basin Plan and approved by the Murray-Darling Basin Authority.

Many uncertainties still remain for managing the rivers of the Murray-Darling Basin equitably. There are long-term and serious environmental impacts still occurring including increased blue-green algal blooms, recent massive fish kills (Australian Academy of Science, 2019) and declining ecosystem health of wetlands, including many of the Ramsar sites for which Australia has international responsibilities. The challenges of managing ecologically complex floodplains and the interface with diversions of water for irrigated agriculture are increasingly difficult. Current legislation and compliance aspects poorly track water diverted from floodplains, reflected in a recent successful prosecution of a cotton grower for stealing water. Further, the Murray-Darling Basin plan has failed to incorporate the long-term effects of climate change in decisions on the necessary amount of water required for sustaining this river basin. For example, while environmental flows would enable restoring waterbird abundances, climate change restricts their improvement significantly (Kingsford, Bino, & Porter, 2017).

To tackle the ecological challenges, a notable feature of the changes in water management is the increasing focus on management of environmental flows, with the Australian Government buying back water from the irrigation industry to return to the river (up to AUD 3.1 billion). The Australian Government held 2,815,100 million litres of environmental flow (Department of Environment and Energy, 2019) in the form of entitlements. State governments have also purchased water for the rivers. Much of this water for the environment is stored in large dams, requiring release and management for environmental purposes, such as flooding wetlands.

These environmental flows have sustained important areas of the river, such as the Macquarie Marshes, a Ramsar-listed wetland relying on upstream water release of the tributary Macquarie River. Since the late 1980s, upstream water allocation has been regarded as a major challenge to the protection and health of the wetland. Irrigation in the upstream catchment changed the flow regime with knock on effects to the habitat of waterbirds and changes in vegetation. Over the years, environmental flows were managed by the conservation agency, though without clear ecological objectives. In 2010, strategic adaptive management was introduced "To restore the Macquarie Marshes so that it has its full functional complexity and ecology (native species, communities and processes), built around productive partnerships" (Kingsford, Biggs, & Pollard, 2011, p. 1196). This process has enabled clarity on what the wetland should look like in the future, along with specification of vital attributes which shapes planning and a nested set of objectives. Furthermore, as management of the wetland is implemented, there are opportunities for learning across a range of stakeholders for enhanced resilience (Kingsford, Biggs, & Pollard, 2011). But this adaptive management planning still lacks institutionalisation.

While such innovation has taken place in some parts of the river, river planning remains incoherent as they are developed under each of the State's respective water legislation (e.g. *Water Management Act 2000* in New South Wales). For some rivers which flow between and even form the border of the different states (e.g. Macintyre River, border of New South Wales and Queensland), this can mean two plans for different sides of the river. The centralisation of water resources development to governmental actors, as opposed to individual riparian right owners, has enabled large-scale hydraulic mission for irrigation and subsequent effects on the ecosystem (Bino, Kingsford, & Brandis, 2016). The irrigation industry remains a powerful stakeholder in influencing government decisions today. The government and irrigation sector have come under intense scrutiny recently after questions arose on the benefits of spending over AUD 5 billion to subsidise irrigation infrastructure for water recovery purposes. Net streams flows have not increased despite these engineering solutions and fall short in achieving objectives of the Water Act 2007 (Grafton et al., 2018).

Social learning processes can only be useful if the engagement becomes diversified with various stakeholders as well as at various scales of management across the basin. The stakeholder base for decision-making is expanding with government involvement in river management committees, with representation from government environment agencies, including fisheries and also conservationists (e.g. Macquarie Cudgegong Environmental Water Advisory Group).[1]

Increasingly, Traditional Owners, whose lives revolve around the rivers and their environments, are taking part in dialogues in addition to floodplain graziers, recreational users, fishers, birdwatchers and other users of the environment. Traditional owners have been largely ignored in the development of rivers, only recently receiving access to cultural flows as a legal right, albeit a small one. There is also increased realisation that landholders who use the many floodplain areas to graze their cattle are also affected by the diversions upstream for irrigation, affecting the landholders' resilience and livelihoods (Hall, 2017; Petersen, 2017).

Among these stakeholders, there is a clear realisation that too much water has been taken from this river basin. The initial steps have been taken where governments have bought water back from the irrigation industry to return to the river and maintain its environmental health. Future challenges evolve around whether enough water was recovered or if regulation is inefficient to stop further water resource development, eroding difficult to achieve gains.

[1] For further details of group, see for example NSW Department of Planning, Industry and Environment (2019).

6 Discussion

The analysis of the Mekong, Colorado and Murray-Darling river basins demonstrates that water use has changed and increased over time, throwing up issues of competing demands. While at different speeds, it is clear to see how the development of these three river basins has stored, diverted and dammed water through the use of various infrastructure. Along this physical development of the river basin, we also see different levels of institutionalisation of rules and practices first to enable further use of the river resources and second to manage incongruous interests of stakeholders. In all three basins, institutions have had to adapt over time to drivers of water use and these interests of stakeholders (see Table 1). Even seemingly static treaties, which are rarely open for wholesale renegotiation, have been part of a deliberative process in which their implementation had been contested, resulting in additional institutional arrangements or further studies, as in the case of Colorado and Mekong river basins. However, the initial phases of river basin development have been driven by a distinct modernist vision, which sees the flows of river as an object of control. Maximising the utility of these flows is particularly evident through the network of infrastructure. This has meant that dealing with ecological impacts has been relatively reactive and at later stages of the development trajectory, though there are some innovative ways in which water for the environment has been considered, as seen in the case of environmental flows in the Murray-Darling.

As the Colorado case study best illustrated, institutionalisation has occurred over time, but in a patchwork fashion with various legal instruments, policies and arrangements. This way of institutionalisation reflects a complex reality where resources are limited to deal with any and all issue relating to river development: issues are inevitably prioritised. Power relations of stakeholders have much to do with the ways issues are prioritised. The hydraulic mission sets into motion a set of institutions that facilitate allocation of water in a centralised fashion with a narrow

Table 1 Evolution of institutions to deal with uncertainties in the Mekong, Colorado and Murray-Darling river basins

	Mekong	Colorado	Murray-Darling
Progress through water management paradigms	Mixture of hydraulic mission and reflexive modernity	Gradual transition from hydraulic mission to reflexive modernity	Gradual transition from hydraulic mission to reflexive modernity
Example of key concern relating to uncertainty	Accelerated dam development	Drought	Declining ecological health
Notable features of institutionalisation	River basin organisation under a formal multilateral agreement	Contemporary additions of agreements that coordinate reservoir levels in times of water shortage to historical agreements and treaties	Basin planning and strategic adaptive management led by the river basin authority and implemented by individual states

set of stakeholders. Consequently, those with water allocation or access to water abstraction tend to have more influence over subsequent decision-making, creating winners and losers including the environment as a notable loser. However, competing water use also means it is impossible to contain deliberation to a narrow set of stakeholders. As the Mekong case study highlighted, the MRC inevitably had to face civil society and their claims regarding the role of the river for livelihoods. The quality of the river basin organisation's engagement requires further scrutiny but the example shows that path dependency of the hydraulic mission can be called into question. In all three river basins, challenging, if not reconfiguring existing power relations becomes the cornerstone in altering existing practices of the hydraulic mission and to exercise reflexive modernity.

A wider set of stakeholders engaging in deliberation over the river basin has meant that mobilising new information and inputs to decision-making have been attempted. The case studies highlighted that while knowledge about livelihoods, local conservation options or environmental flows are sought, it does not necessarily mean that new knowledge replaces those used to inform the hydraulic mission. In other words, technocratic or engineering knowledge is not entirely replaced with other forms of knowledge. In fact, different kinds of knowledge exist and are used in different ways by stakeholders to best advance their interests. Here we see plural forms of knowledge which has the potential to challenge and destabilise existing practices, but not a panacea as the Mekong example showed.

This point is insightful when thinking about how uncertainty is dealt with in basins facing multiple stressors and risks. In the Colorado river basin, it was shown that the variability of water flows has been a highly significant issue in recent years, which has in fact created opportunities for local conservation efforts. These local efforts will enable stakeholders to acquire experiential knowledge, which are separate from scientific knowledge on hydrological factors. In the Mekong, when dam development accelerated, concerns of uncertainty were not considered in detail initially. This meant that there was a narrow parameter of what was considered uncertain. While it cannot be said that alternative views regarding trade-offs of dams have been accepted, the continual contestation indicates that understanding of uncertainty can be shaped and reshaped by engagement of stakeholders. In contrast, the case of the Murray-Darling emphasises the temporal aspect of uncertainty: existing arrangements to ameliorate over-abstraction has been critiqued as falling short of being effective and raises questions about the extent of future proofing.

In all three basins, it is clear that business as usual will not suffice to deal with the pace of changes in the basin with both physical and socio-economic dimensions. The cases show that adaptive management, IWRM and adaptive governance approaches have been attempted in varying degrees in an attempt to seek water resilience. However, the trajectory of the basins showed that the start of water resilience paradigms is not clear-cut and there is a significant period of transition. It is in this period of transition where we see an overlap of hydraulic mission practices and reflexive exercises. It has been critiqued that top-down centralised practices are rigid and hard to change, however, the empirical experience showed that learning by doing is equally slow to reap rewards. Adaptive governance approaches help bring to the fore contested values over the river and its resources. Nevertheless, its novelty does not guarantee a 'fix-all'. IWRM falls short in many of the river basin realities and a simple integration of sectors does not provide answers to the various uncertainties posed.

Water resilience in these cases means more than simply to accommodate drivers of change and pace of such change. Here, the cases demonstrate what has been termed as 'negotiated resilience' (Harris, Chu, & Ziervogel, 2017). Negotiated resilience is understood as a process, rather than a goal, in which key questions around resilience are considered by diverse stakeholders. Resilience can be seen through the perspective of stakeholder interests, scales at which institutionalisation has occurred or through temporal dimensions. Put differently, iteratively defining and determining resilience is in fact the focus, rather than taking for granted what water resilience might stand for. That is why the case studies demonstrate a transition-like state of the hydraulic mission to water resilience paradigm. It can be said from the case studies that an objective state of resilience has not been identified in any of the basins. The trajectory of each river basin and their patchwork of institutionalisation contribute to a unique set of circumstances for discussing how resilience can be understood. Importantly, this deliberation is buttressed by power relations. The case studies provide an appreciation of the way power is exercised through different knowledge and social learning. In this way, enhancing resilience may expose power asymmetries and uncomfortable processes in which such asymmetries need to be addressed. Interventions to enhance resilience are not always harmonious (Hahn & Nykvist, 2017).

Negotiated resilience assumes multiplicity in understanding by a range of stakeholders (Harris et al., 2017). The multiplicity derived from these stakeholders thus makes "any discussion or planning for 'resilience' necessarily political and contested" (ibid, p. 203). The case studies show that multiple stakeholders emerge with divergent and varying interests and priorities as the paradigms of water development gradually advance through and beyond the hydraulic mission. There are multiple views as to what interventions or actions are best suited to adapt to changing water demands and pressures on the basin. Some views are more easily taken up in mainstream decision-making, while others need to seek legitimacy. The contestation over river management options reflects that a fixed understanding of resilience is hard to come by. Rather, water resilience is one of continual negotiation and deliberation that are shaped by stakeholders and what they claim as necessary, important or effective for river basin management. This version of water resilience may be more effective at tackling the problems observed in the broader resilience literature where uncoordinated changes or those done with a narrow view without consideration to the overall system yield 'undesirable resilience', 'unhelpful resilience' or 'wicked resilience' (Oliver et al., 2018). Moreover, the insights from the case studies highlight that resilience is normative (see Brown, 2011) and that the application of such normative concept needs to be worked out in a grounded, unique context.

Based on the above discussion, there are some policy lessons that can be derived from the individual cases as well as the combined insights from the three river basins. First, it could be suggested that policy needs to support a continual process where stakeholders can extend their networks and work out new relations between them so as to ensure there are opportunities for social learning and deliberations. This is not to say that there will be successful social learning or that social learning will be able to intentionally put in place mechanisms to enhance resilience. In fact, these are not a given and the second policy lesson is the need for a realistic expectation that getting water resilience ‘right’ is not easy and requires scope for multiple approaches to dealing with change. The third lesson is that where institutions are in place, they need to be continually invested to avoid becoming a defunct organisation: investment will likely be in the form of updating norms, protocols, agreements, revising the scope of committees so as to take into consideration drivers of water use from other sectors or factors such as climate change.

7 Conclusion

This chapter showed how river basin development occurs over time with varying opportunities for institutionalising water resources management and governance. The Mekong, Colorado and Murray-Darling river basins have experienced the hydraulic mission at varying paces as well as the effects of intense infrastructure development. These basins have been the stage for serious trade-offs that relate to economic benefits, ecological health and livelihood options. These trade-offs are notably raised by and concern a diverse set of stakeholders. These stakeholders attempt to deal with complexity and uncertainty, with use of knowledge or social learning for example. Water resilience in these cases is not an evident, fixed or neutral state to strive towards under the consensus by all stakeholders. Rather water resilience is contested and negotiated by multiple stakeholders, and continually evolves with the trajectory of the basin. The policy lessons therefore are about understanding what water resilience means in a specific basin as a start, based on a wide range of inputs from stakeholders. The lessons also point to strengthening institutions so that they are continually relevant and instrumental to enabling the process of deliberation, not restricting it.

The analysis presented in this chapter provided snap shots of how water resilience is articulated and debated. In particular, the study highlighted how power relations throw up contestations in the process of ‘learning by doing’, or in seeking flexibility for adaptive governance approaches. The findings from the three case studies indicated that resilience is indeed contested and power laden. In addressing water resilience, power is expressed through the way is knowledge is mobilised and networks of actors shaped. Further research can provide a more comprehensive insight to the power relations of stakeholders and their claims and influence for ‘negotiated resilience’. The degree to which deliberations are politically charged differs across basins. However, the overview across the three differently endowed river basins has merit in underscoring the intractable nature of water development issues.

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Conditions and Cautions for Transforming Ocean Governance

Jessica Blythe, Derek Armitage, Nathan Bennett, Jennifer J. Silver, and Andrew M. Song

Abstract This chapter explores the circumstances under which ocean governance transformations can occur. We analyze three ongoing cases of transformation to identify enabling conditions and points of caution for transformation in the dynamic and complex field of marine management. Our cases include: (1) the Food and Agricultural Organization's (FAO) small-scale fisheries guidelines, (2) debt-for-'blue'-nature swap in the Seychelles, and (3) the United Nations' negotiations for a legally binding treaty to govern the high seas. Through our analysis, we find that preparing for transformative change is enabled by the identification of a governance related challenge, growing social support for governance change and the communication of compelling narratives. Windows of opportunity can be opened through policy negotiations and social or ecological crises. Navigating governance transitions can be facilitated through multi-stakeholder collaborations and building resilience with the new governance regime is predicated on contextualized institutional support. We also find that caution should be exercised in accounting for the diversity of policy landscape within which governance transformations occur, the uneven distribution of the costs and benefits of governance change, and conflicting perspectives on the appropriate direction of change. The three cases examined in this study offer insights into the processes required to initiate and navigate governance transformations in marine and coastal social-ecological systems. Ultimately, we aim to

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contribute to ongoing efforts to better understand processes that facilitate governance transformations towards more sustainable and equitable oceans.

1 Support for Ocean Governance Transformation

In the Anthropocene, arguments for ocean transformation abound. In the Pacific, for example, the non-governmental organization Oceans 5 is working with the Government of Tonga on a collaborative a project that aims to "transform the management of Tonga's entire ocean" through comprehensive marine spatial planning (Oceans 5, 2019). In California, The Nature Conservancy (TNC) is supporting what they described as radically new approaches for ocean governance with the potential to "transform fisheries management" (TNC, 2018). And globally, the United Nations Sustainable Development Goals (SDGs), which include SDG 14 or 'Life Below Water', was launched with the intention of "transforming our world" ([UN], 2015).

The need for ocean governance transformation is justified in several ways. The first relates to building ecological resilience. Once understood as immense and remote spaces, oceans are now seen as highly vulnerable to anthropogenic pressure (Bennett, Blythe, Tyler, & Ban, 2016; Dulvy & Kindsvater, 2017). Climate change, land-based pollution, unsustainable resource extraction, and habitat degradation threaten to push marine systems beyond their capacities to support ecosystem function and societal well-being (Nash et al., 2017). In 2016, for example, one third of the Great Barrier Reef, the world's largest coral reef system, experienced severe bleaching as the result of a record-breaking marine heatwave (Hughes et al., 2018). More than half of the world's oceans are subject to industrial fishing and global catch is declining as fishing effort continues to rise (Watson et al., 2013). Building resilience, which describes the ability of a systems to anticipate, adapt or transform in the face of change, is seen as a promising approach for management and governance in times of change (Folke et al., 2010).

A second rationale relates to increasingly uneven access to ocean benefits. Evidence of social injustices in ocean governance is mounting (Bennett, 2018; Silver, 2014; Song, Bodwitch, & Scholtens, 2018). For example, declining catch and profits coupled with weak governance and enforcement has been linked with rising instances of labour abuses, such as forced labour or debt bondage (Tickler et al., 2018). In many places around the world, coastal and Indigenous communities experience barriers to marine resources access (Bennett et al., 2018). The global push for economic development of the world's oceans, often associated with the term 'the blue economy', has triggered concern about the exclusion of coastal communities from accessing ocean benefits (Bennett et al., 2019; Bennett, Blythe, Cisneros-Montemayor, Singh, & Sumaila, 2019).

A third argument for ocean transformation relates to the exclusion of local voices in many contemporary governance approaches. In Solomon Islands, for example, decentralized community-based resource management has been widely implemented based on its potential to assist remote coastal communities to take ownership of local marine management decisions. Yet in practice, local elites, such as members of reef-owning clans, often dominate decision-making processes at the exclusion of more marginalized members of the community (Blythe et al., 2017). Moreover, in some cases, such as coastal Indigenous communities in Canada and New Zealand, externally imposed marine governance policies not only exclude local participation, but can also create significant damage to local resource bases and traditional knowledge (Turner, Berkes, Stephenson, & Dick, 2013).

These arguments in support of ocean governance transformation are put forward by different groups (e.g., governments, civil society, NGOs, etc.). Advocates for various governance approaches support diverse transformative agendas with often widely different objectives and strategies (Jupiter, Cohen, Weeks, Tawake, & Govan, 2014). Thus, it can be difficult to distill common characteristics of ocean governance transformation, particularly since much of the ocean transformation research to date is ad hoc and/or highly localized (Blythe, Cohen, Abernethy, & Evans, 2017).

Our objective in this chapter, then, is to explore the circumstances under which governance transformations can occur. Importantly, our intention is not to evaluate the normative dimensions of governance transformations, diagnosing outcomes as good or bad, helpful or harmful, successful or unsuccessful. We recognize that radical reform in governance actors, decision-making processes or institutions will necessarily produce widely uneven impacts that challenge normative diagnoses (Blythe et al., 2018). Rather, our aim in this chapter is to deepen understanding of enabling conditions under which transformation can occur and points of caution, in other words places where care can be taken to avoid the risks associated with transformative change. Understanding these processes is useful for informing actions to either support or contest any new governance trajectory (Gelcich, Reyes-Mendy, & Rios, 2019; Moore et al., 2014).

Following this introduction, we define ocean governance transformation and present a framework for assessment for ocean transformation in Sect. 2. In Sect. 3, we describe the conditions that enable (or hinder) ocean governance transformations in three recent, or ongoing, cases: (1) the Food and Agricultural Organization's (FAO) small-scale fisheries guidelines, (2) debt-for-'blue'-nature swap in the Seychelles, and (3) United Nations' negotiations for a legally binding treaty to govern the high seas. In Sect. 4, we synthesize the conditions and cautions that emerge from the cases. In Sect. 5, we reflect on the relevance of these insights for informing future governance transformations.

2 Defining and Analyzing Ocean Governance Transformation

As scientists, policymakers, and practitioners advocate for transforming ocean governance, it becomes necessary to ask: *how are governance transformations defined?* In many instances, "it is not clear what is being transformed, by and for whom, and through what processes" (Scoones et al., 2018, p. 5). Moreover, the idea of transformations towards sustainability is characterized by a variety of interpretations (Feola, 2015). While the literature remains characterised by a diversity of interpretations, four general framings of transformations have emerged. First, a socio-technical transitions approach contends that transitions towards low carbon futures result from niche innovations that feed into existing socio-technical systems to disrupt broader political and economic landscape (Geels, Sovacool, Schwanen, & Sorrell, 2017). Second, the social-ecological systems perspective conceives of transformations as novel feedbacks in complex systems (Moore et al., 2014). Third, the sustainability pathways approach, which was developed in the Social, Technological and Environmental Pathways to Sustainability (STEPS) centre in the United Kingdom, emphasizes the need to consider the power and politics of transformative change to better ensure both ecological sustainability and social justice (Leach et al., 2012). Fourth, the transformative adaptation perspective focuses transformative analyses on the underlying social, political, and economic structures that produce marginalisation and inequality (O'Brien, 2012; Pelling, 2010). In this chapter, we engage with the social-ecological systems perspective of transformations because it has become a prominent paradigm in academia and ocean governance policy and practice.

Common across many perspectives on transformation is the notion that governance transformations are defined as 'radical' and deliberate changes in system structures when existing ecological, social, or economic conditions become unfavourable (Folke et al., 2010). Governance transformations can modify public policy objectives and include new management visions and actors in a reformed decision-making process (Olsson, Folke, & Hughes, 2008). Hence, governance transformations differ from new policies that entail incremental shifts in existing structures or processes (Gelcich et al., 2019).

Building on this definition, a second important question becomes: *how can we effectively analyze governance transformations?* Towards this purpose, Olsson, Folke, and Hahn (2004) developed a useful framework to analyse governance transformations from a social-ecological systems perspective. The framework conceptualizes transformations as a process comprised of three, iterative phases: (i) preparing for transformation, (ii) navigating a transition, and (iii) building resilience within a new system trajectory (Fig. 1). Application of this framework, or adaptations of it, have been used to examine key social and ecological outcomes associated with governance transformations (Armitage, Charles, & Berkes, 2017; Armitage, Marschke, & Van Tuyen, 2011; Blythe, Cohen, et al., 2017; Gelcich et al., 2010).

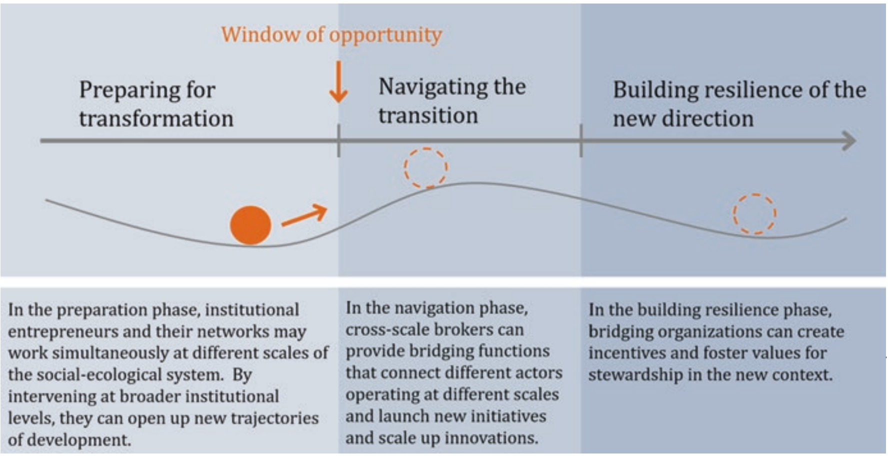

Fig. 1 Three phases of transformation in social-ecological systems (from Stockholm Resilience Centre, 2011). (Source: Olsson et al., 2004; Folke et al., 2009)

with crises and tensions and are understood as critical for generating new inspiration for transformational change (Westley & McGowan, 2017). Windows of opportunity are often multiple, not singular (Blythe, Cohen, et al., 2017). They can emerge in response to convergence of many, multi-scaled processes, some peripheral to the transformation of focus. According to Olsson et al. (2004), windows of opportunity can open when an acute problem, a contextually appropriate solution and a conducive political climate collide.

The second phase involves navigating the transition. In the second phase, the coordination of innovations and experimentation across scales has proven to be an effective mechanism for navigating transformational change (Olsson et al., 2006). In Chile, for example, the emergence of democracy after nearly two decades of dictatorship, new fisheries legislation that introduced territorial user rights for fisheries (TURFs), and zoning that assigned exclusive rights to artisanal fishers within 5 nautical miles of the coast coalesced to foster marine governance transformation (Gelcich et al., 2010).

In the final stage, building resilience, new systems configurations become institutionalized. Bridging organizations have played critical roles in fostering horizontal and vertical linkages that foster resilience. The last phase puts emphasis on the need to institutionalize any new trajectory (Moore et al., 2014) and is critical for the new governance regime to be correctly implemented, persist, and increase its legitimacy. The nature of governance transformations suggests that an early assessment of the new institutional model and decision-making process is critical to address institutionalization problems and fine-tune the process through which governance transformations can be successfully implemented (Gelcich et al., 2019).

While support for governance transformations is growing, understanding of the contexts in which transformations can occur remains a challenge. According to the Stockholm Resilience Centre (2011), "there is still a lack of understanding of the mechanisms and patterns involved, and of the conditions under which critical transformations can emerge. This lack of understanding greatly decreases the chances for successfully navigating transformations and embarking upon sustainable trajectories" (p. 1). Moreover, it is not always clear what is being transformed, or for whom? Problems of scale and the durability of a 'transformation' further complicate with efforts to assess transformations. As a result, much of the theoretical work remains generic, while empirical work focuses narrowly on the triggers of transformative change and downplays the importance of navigating turbulent transitions and what those entail (e.g., shifts in power). In the next section, we unpack key enabling conditions for transformational change through analysis of three ongoing cases of transformative ocean governance.

3 Three Cases of Ocean Governance Transformation

During the last decade, an extraordinary variety of radically new approaches for ocean governance has proliferated. These ocean governance transformations provide useful opportunities to explore the conditions that catalyze and shape transformational change.

In order to better understand how transformational change might occur and be supported, we selected three cases of ocean governance transformation that have recently occurred or are currently unfolding. We purposefully selected cases that illustrate various stages of the social-ecological transformational change process (Fig. 2). Analysis of the various stages of change can be used to identify barriers and enablers of governance transformations. Moreover, we selected cases that illustrate governance transformations at scales ranging from local to global. In the first case, we explore the Food and Agricultural Organization's (FAO) recently proposed Small-Scale Fisheries Guidelines, which illustrates an international scale governance transformation that is moving into the resilience building phase. Second, we explore the emergence of so called 'debt-for-'blue'-nature swaps' by delving into an example from the Seychelles, which represents a local scale governance transformation that is moving out of the navigating phase into the resilience building phase. Through the third and final case, we explore the ongoing United Nations negotiations for a legally binding instrument to govern the high seas, which illustrates an international scale governance transformation that is beginning the navigation phase.

We used multiple methods to conduct our analysis (Burnham, Lutz, Grant, & Layton-Henry, 2008). The first method we employed was document analysis, through which we aimed to identify common barriers and enablers of marine governance transformation (Bowen, 2009). The documents we analyzed included official policy documents, peer-reviewed papers, and grey literature associated with the three cases. Based on our document analysis, we drew on the expert judgement of the main authors who have been involved to various degrees in ongoing research around each case for years. Expert judgement involves providing experts with a structure framework to help identify common characteristics, optimal policy decisions or research frontiers (Burgman et al., 2011). The methodology is well suited

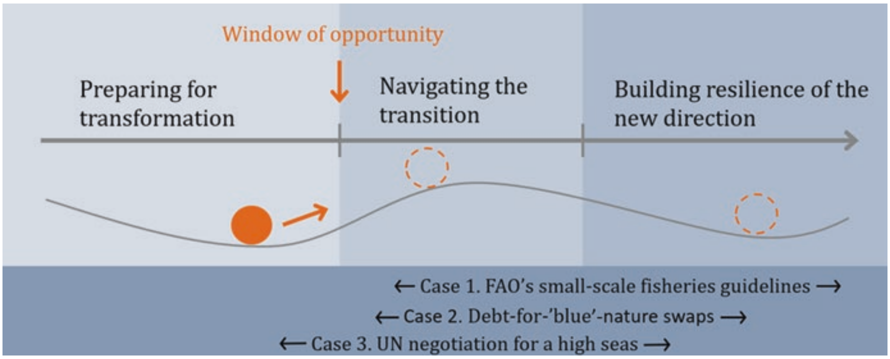

Fig. 2 Three cases analyzed in this chapter, which are in various phases of the social-ecological transformational change process (top panel from Stockholm Resilience Centre, 2011)

to dealing with complexity and uncertainty and is routinely employed in fields such as ecology, health, and engineering (Burgman et al., 2011). Specifically, our expert judgment was guided by three central questions:

1. What conditions characterized the preparation phase? Why was governance transformation perceived to be necessary (and by whom)?
2. During the navigation phase, by whom (the actors) and how (the institutions and decision-making processes) were new governance objectives pursued?
3. What factors enabled the institutionalization (or resilience building) of the new governance approach?

Using these three guiding questions, we assess the main possibilities and obstacles for transformational ocean governance and delve deeper into the conditions under which transformation can occur.

3.1 FAO's Small-Scale Fisheries Guidelines

The Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication ('the SSF Guidelines') led by the FAO is the first internationally agreed policy instrument dedicated to the small-scale fisheries sector. Its publication in 2014 is heralded as a landmark moment that significantly elevated recognition of small-scale fisheries in the global fora, amidst the historic neglect of the sector in comparison to large industrial fishing operations and competing non-fisheries developments (Jentoft, 2014; Jentoft, Chuenpagdee, Barragan-Paladines, & Franz, 2017). Comprehensive in its scope, the SSF Guidelines are meant to be a tool to guide dialogue, policy processes and action at all levels and for all stakeholders. Its transformative and innovative appeal is also said to lie in the application of human rights principles in its rationale and design (Song & Soliman, 2019; Willmann, Franz, Fuentevilla, McInerney, & Westlund, 2017).

3.1.1 Preparing for Transformation

Preparations for the eventual introduction of the SSF Guidelines were geographically and temporally diffuse over many decades and regions, often involving unseen grassroots struggles that fought for the rights, livelihoods and dignity of small-scale fishers against the trends of over-commercialization, modernization and westernization in fisheries. Civil society organizations such as the International Collective in Support of Fishworkers (ICSF), the World Forum of Fisher Peoples (WFFP) were at the centre of this battle. Over time, academic literature that documented and highlighted the unique characteristics and development needs of small-scale fisheries was also gaining momentum as an important body of research (e.g. see the work of Conner Bailey, Fikret Berkes, Bob Johannes, John Kurien, Bonnie McCay, Daniel Pauly, Jean-Philippe Platteau, & Ken Ruddle).

3.1.2 Window of Opportunity

A watershed event came in 2008 when FAO and the Thai government, with help of the Southeast Asian Fisheries Development Center (SEAFDEC) and WorldFish, convened the Global Conference on Small-Scale Fisheries in Bangkok. Arguably, a significant catalyst was the Statement from Civil Society Workshop that was formulated immediately prior to the conference and presented to the audience. This collective voice of fisher representatives striking synergy with the supportive stance of academic and inter-governmental experts created a timely opening, through which the call for an international instrument on small-scale fisheries was galvanized and put into action (FAO, 2009b). In the following year, the 28th Session of the FAO Committee on Fisheries (COFI) formally expressed the need for such an instrument, and FAO began to conduct regional workshops to consult with national and regional stakeholders.

3.1.3 Navigating the Transition

The transition towards formalizing the creation of the SSF Guidelines was facilitated via the Committee on Fisheries (COFI) meetings (i.e., the 29th session held in early 2011 approved the development of the text, while the 31st session held in June 2014 endorsed the final draft). Interestingly, at an operational level, the forging of an informal partnership between the academic community and FAO was observed, in which the former supplied scholarly justification to the latter while the latter provided policy relevance and governmental legitimacy to the work of academic researchers. Together, this "alliance" helped generate sustained excitement about the creation of the document. For instance, FAO personnel was on hand at the 2nd World Small-Scale Fisheries Congress held in 2014 in Mexico to introduce the text of the SSF Guidelines to the academic circle and fisher representatives and receive guidance for initiating national-level uptake. In the same vein, a major academic output detailing the anticipated implementation of the SSF Guidelines sought close collaboration with the several champions of the SSF Guidelines within the FAO (see Jentoft et al., 2017). As a result of the global, official coordination as well as a participatory approach taken to consult over 4000 people—including fishers, CSO activists and state representatives—in 120 countries, optimism is real in many parts of the world, with various regional and national processes set up to facilitate contextualized adoption (e.g. Southeast Asia – FAO, 2015a; Brazil – International Guidelines for Small-Scale Fisheries [ICSF], 2016; West and Central Africa – Franz, Smith, & Westlund, 2019).

3.1.4 Building Resilience

Structured and targeted support is key to accelerate the integration of the SSF Guidelines into the policy documents and legislations of developing countries where much of small-scale fisheries reside. FAO is in the process of creating the Global Assistance Programme framework to advance capacity development, institutional strengthening, awareness raising and knowledge sharing (FAO, 2015b). As implementation efforts ramp up, a sensitive approach to engaging with each regional and national context will prove critical. Not doing so risks overlooking an area's unique 'policyscape' and thereby misjudging the shape and level of incentives that exist for the uptake of the SSF Guidelines. In the Pacific Island region, for example, enthusiasm about the SSF Guidelines has been somewhat lacking in comparison to other regions (Song et al., 2019). Procedurally, that Pacific representation was sparse from the drafting and consultation processes is a plausible contributing factor to this relative apathy (Nisa, 2014). Structurally, the Pacific Island region has developed a number of region-specific small-scale fisheries policies, including the 2015 Noumea strategy, called the 'New Song'. A greater familiarity with regional processes and more contextualized policy products (i.e., national fisheries agencies have been part of drafting these documents) have likely added to the increased awareness of regional guidelines over the SSF Guidelines so far. As a result, by 2017, many government fisheries officers in the region have not heard of the SSF Guidelines, let alone have been using it to guide their countries' fisheries management programmes (Song, Cohen, Hanich, Morrison, & Andrew, 2019). However, the high degree of thematic overlap, or policy coherence, between the SSF Guidelines and the region-specific documents presents an encouraging institutional starting point for building a lasting governance transformation that will benefit the small-scale fisheries of the Pacific Island countries (Cohen, Song, & Morrison, 2017; Song, Cohen, & Morrison, 2017).

3.2 Debt-for-'Blue'-Nature Swaps in the Seychelles

The *Debt Restructuring for Marine Conservation and Climate Adaptation Program* is an ocean governance arrangement that encompasses the entire Exclusive Economic Zone (EEZ) of a single Small Island State. It is the result of a formalized collaboration between international environmental NGO, The Nature Conservancy (TNC), and the Government of The Republic of Seychelles. The arrangement was designed to restructure a portion of debt owed by the Government of Seychelles to the Paris Club of Creditors and redirect debt payments and interest towards marine conservation projects. In exchange for debt restructuring, the Government of Seychelles has committed to marine spatial planning throughout the full extent of its 1.37 million km^2 EEZ and to setting aside 30% for marine conservation. Of that 30%, 15% will be designated as a 'no-take' marine protected area (for additional details, see: Silver, Gray, Campbell, Fairbanks, & Gruby, 2015; Silver & Campbell, 2018).

3.2.1 Preparing for Transformation

Inspired by the decades old 'debt-for-nature' model (Reilly, 2006), TNC developed a relationship with the Government of The Republic of Seychelles prior to the 2012 United Nations Conference on Sustainable Development (i.e., 'Rio + 20'). In approximately 2011–2012, TNC began to explore the possibility of a debt restructuring with The Paris Club. While the Government of Seychelles had hoped to achieve a deal that restructured up to US$80 million of debt, a figure of US$21.6 was ultimately agreed upon. In order to formalize the deal and create a structure for transferring and overseeing the debt, the Government of Seychelles passed a piece of national legislation, the 'Conservation and Climate Adaptation Trust of Seychelles Act', in 2015. Notably, this included bringing an 'arms-length' institution called the Seychelles Conservation and Climate Adaptation Trust (SeyCCAT) into existence.

3.2.2 Windows of Opportunity

Key conditions for this governance arrangement relate to two windows of opportunity. The first window stems from the fact that many Small Island and Coastal Developing States struggle under debt burdens. King and Tennant (King & Tennat, 2014) relate this pattern to a domestic economic development approach that prioritizes export-led industrialization. Starting in the 1970s, many developing countries were encouraged by the international community to open up their borders and markets; the question was not whether to accumulate national debt, but how much was necessary and appropriate to stimulate macro-economic conditions attractive to foreign capital. Today, countries like the Seychelles are looking for creative and proactive ways to pay down debt while retaining connectivity with global investors and markets.

The second window opened with growing international attention to oceans and marine conservation. Over the last 15–20 years, oceans have become an important centerpiece to global environmental governance conferences and initiatives and prominent international organizations have sought large-scale fisheries management and marine conservation 'solutions'. Marine Spatial Planning (MSP) and Large Marine Protected Areas (LMPAs) are attractive because they offer frameworks that seek to integrate attention to ecological habitat and connectivity, livelihood activities, property rights, and enforceable boundaries.

3.2.3 Navigating the Transition

At Rio + 20 and in the years immediately after, the Seychelles positioned itself as a leader in novel approaches to and arrangements for sustainable ocean development and marine conservation. For its part, TNC heralded the debt restructuring model as a 'win' for marine conservation. SeyCCAT was at the centre of the debt transaction itself. Specifically, it used US$20.2 million convened by TNC from donations and private 'impact investors' to buy back a portion of the Seychelles' debt from The Paris Club at a reduced rate. Instead of making payments to The Paris Club, The Government of Seychelles now owes SeyCCAT installments to be paid in local currency and at a reduced interest rate. SeyCCAT uses these funds to support conservation projects and the MSP process. TNC asserts that it will continue to play a role 'on-the-ground' by monitoring ecological outcomes and facilitating MSP. It is now also promoting the idea that the debt restructuring model should be replicated in the EEZs of other Small Island and Coastal Developing States.

3.2.4 Building Resilience

The Seychelles has identified and formally demarcated the agreed upon 30% of its EEZ, and local marine conservation projects have begun to be funded through SeyCCAT. To ensure resilience, the social and ecological outcomes of the *Debt Restructuring for Marine Conservation and Climate Adaptation Program* will have to be monitored carefully over time. For example, there have been some media reports wherein local fish harvester groups express concern over planning processes and new exclusions from important fishing grounds. Likewise, biodiversity measures in conservation and no-take areas will need to be periodically evaluated to ensure maximum positive ecological impact. However, it is important to conclude with the point that this ocean governance model rests on a fundamental and unresolvable tension with implications for resilience: it is predicated on an economic development approach that opens up small island and coastal developing state economies and may render them *more* vulnerable to international market fluctuations and the uneven power dynamics of foreign investment and multilateral negotiation.

3.3 United Nations Negotiations for a Legally Binding Treaty for the High Seas

The high seas cover two thirds of the world's oceans and provide vital services including the generation of oxygen, regulation of climate and fishing. Yet, less than 1% of the high seas is formally managed. Between 2018 and 2020, member states of the United Nations are negotiating a new, global legally binding treaty that could transform ocean governance at a scale unseen in four decades (Jacquet & Jackson, 2018).

In 1982, governance of the world's oceans was redefined through the United Nations Convention on the Law of the Sea (UNCLOS). Before the 1982 UNCLOS, countries generally controlled access and harvesting rights in their territorial waters, which extended 3 nautical miles. After the 1982 UNCLOS, exclusive economic zones (EEZ) were established. EEZs extend from national coasts out to 200 nautical miles and nations were prescribed formal governance control of their EEZs.

At this point in time, waters beyond national EEZs, generally referred to as the high seas, were considered international waters and free to all nations to access (High Seas Alliance [HSA], 2019). In the early 1980s, few nations had the need or the technological capacity to fish in the high seas, so overexploitation resulting from the lack of formal high seas governance was of little concern.

Yet, pressures on the high seas began to rise throughout the 1980s and 1990s. Technology improved, demand for mineral resources mounted, new global markets outpaced outdate governance, and coastal fisheries became depleted, pressures on the high seas began to grow. As coastal waters became overharvested and new markets emerged, fishing fleets exploited marine resources in increasingly distant waters. For example, catch from the high seas has risen from less than two million tonnes in the 1950s to more than ten million tonnes in recent decades (FAO, 2009a). Moreover, two-thirds of stocks fished on the high seas, including high-value toothfish, tuna, sharks and billfish, have been quantified as either depleted or overexploited (Cullis-Suzuki & Pauly, 2010).

Technology increased fishing capacity. But it also allowed us to better understand the global impact of commercial fishing on the high seas (Kroodsma et al., 2018). The emergence of automatic identification systems (AIS) systems, satellite remote sensing, among others over the last two decades, heightened awareness of the immense impacts of fishing on the high seas.

3.3.1 Preparing for Transformation

In 2004, the United Nations General Assembly (UNGA) established an ad hoc working group to study biodiversity beyond national jurisdiction (BBNJ) (HSA, 2019). After two years, the BBNJ working group identified significant governance gaps and called for immediate action, which led to the adoption of Resolution 61/105 on bottom fishing in areas beyond national jurisdiction (ABNJ). This resolution aimed to mitigate the adverse impacts of seep-sea fisheries on cold-water corals, sponges, seamounts and other vulnerable benthic ecosystems and species. Building on this momentum, the United Nations' 2030 'Future We Want' agenda established a deadline for a new implementing agreement for the high seas. In 2015, the United Nations general assembly adopted resolution 69/292, which recommended the development of an implementing agreement (ibid). By 2017, the UNGA adopted resolution 72/249 for an intergovernmental panel to convene four meetings between 2018 and 2020 to negotiate an international legally binding treaty to govern the high seas (ibid).

Concurrently, a proliferation of scholarly publications on the social, ecological, and economic benefits of transforming high seas governance added momentum during the preparation phase. As early as 2001, academics such as Kirstina Gjerde, were exploring the potential benefits of marine protected areas on the high seas (Gjerde, 2001). In 2007, Rashid Sumaila and colleagues conducted an economic cost-benefit analysis of establishing no-take marine reserves on the high seas. Their study concluded that no-take closures on the high seas could provide substantial benefit the international community, through protected biodiversity at relatively little cost (Sumaila, Zeller, Watson, Alder, & Pauly, 2007). Within the last five years, publications on the governance of the high seas have increased exponentially. For example, the high-impact journal *Science Advances* published a special feature devoted entirely the high seas in 2018. Importantly, much of the academic work in this space highlighted the highly uneven access to high seas fisheries and the exclusion of poor coastal nations (Blasiak, Jouffray, Wabnitz, Sundström, & Österblom, 2018; Schiller, Bailey, Jacquet, & Sala, 2018).

3.3.2 Window of Opportunity

Following more than two decades of preparation, the first of four intergovernmental negotiation sessions for a new legally binding treaty to govern the high seas was held at the United Nations in September 2018. The negotiations, which were launched by the United Nations General Assembly in Resolution 72/249 of 24 December 17, provide an opportunity for delegates to draft the terms of a new high seas treaty under the 1982 United Nations Convention on the Law of the Sea (UNCLOS). The instrument's substantive elements will likely include a mechanism to establish Marine Protected Areas (MPAs) on the high seas and require environmental impact assessments for many human activities that happen in areas beyond national jurisdiction. These negotiations provide what has been called a 'once in a lifetime opportunity' to protect the biodiversity and functions of the high seas (HSA, 2018).

3.3.3 Navigating the Transition

The first step in the navigating stage will be the establishment of an international legally binding treaty to protect the high seas. Through the ongoing negotiations, member states of the UN are discussing the potential merit of marine protected areas (MPAs), environmental impact assessments (EIAs), and benefit sharing and technological transfer as mechanisms to support the effective governance of the high seas. As the negotiations will not conclude until 2020, we look to our first and second cases for enabling conditions during the navigation and resilience building phases. However, it should be noted that tensions are arising around the level of protection within the treaty. Some parties, particularly academics, are advocating for large, fully closed areas with no extractive activity, while others are encouraging for more mixed-use areas. This tension raises an important point of caution, namely how to balance multiple, conflicting interests and the inevitable social-ecological outcomes of radically new governance regimes.

4 Conditions and Cautions for Ocean Governance Transformation

Understanding the conditions under which ocean governance transformations occur remains a critical frontier for supporting effective marine management in times of change. Indeed, transformational change is seen as a central component of resilience approaches to governance that are inclusive, adaptive and responsive to contemporary contexts (Folke et al., 2010). While we acknowledge that transformative change will always be unpredictable and non-linear (Blythe et al., 2018), distilling common conditions that enable and constrain the various phases of transformation is useful for refining assumptions that inform future work (Moore et al., 2014). We begin our discussion by synthesizing the enabling conditions that have facilitated transformations in ocean governance across the three cases (Table 1).

Overall, transformations scholars agree that radical change is preceded by a preparation phase. Naomi Klein, for example, describes how a shared vision for the future and collective social action can lay the foundations for transformational change (Klein, 2017). In the context of ocean governance, identification of a management or governance challenge is one condition that can prepare systems for change (Table 1). In the lead up to the UN negotiations for a treaty to govern the high seas, decades of academic research and public discourse generated an increasing appreciation that high seas governance required a change. Similarly, growing concern about the limited capacity of centralized management to effectively govern remote coastal fisheries contributed to a national shift towards community-based resource management in Solomon Islands (Blythe, Cohen, et al., 2017). Secondly, growing social support for governance change can prepare a system for change (Table 1). In the case of the small-scale fisheries guidelines, various groups helped

Table 1 Key enabling conditions throughout the phases of ocean governance transformation

Phase	Enabling conditions (with examples from the three cases)
Preparing for transformation	***Increasing awareness of a governance related challenge*** Recognition that existing high seas governance institutions were unfit to manage contemporary threats of overfishing, climate change, habitat loss and plastic pollution (Case 3) ***Growing social support for governance change*** Informal groups of individuals and organizations working towards governance arrangements that prioritize the recognition of rights, livelihoods, and dignity of small-scale fishers (Case 1) ***Creating and communicating narratives about the need for transformation*** Academics working with organizations, such as the FAO and the TNC, supported the development and communication of compelling stories in support of transformative change (Cases 1, 2 and 3)
Windows of opportunity	***Policy negotiations*** The FAO and the Thai government hosting a global conference on small-scale fisheries, which catalyzed a series of international consultations (Case 1) and the United Nations hosting a negotiation process to develop a legally binding treaty to protect the high seas (Case 3) ***Crises*** The debt burdens of Small Island and Coastal Developing States created financial incentives for novel marine governance arrangements (Case 2)
Navigating the transition	***Multi-stakeholder collaboration*** Formal consultation with 4000 people - plus an informal partnership between the FAO and academic community - supported the legitimacy of the SSF Guidelines (Case 1) Partnership between the Government of Seychelles, TNC and SeyCCAT helped operationalize the new large MPA in the Seychelles (Case 2)
Building resilience	***Contextualized institutional support for the new regime*** TNC is providing monitoring and evaluation support to track the outcomes, and inform the ongoing management, of the new marine governance regime in Seychelles (Case 2) The lack contextualized institutional support (including limited institutional awareness) has slowed the uptake of the SSF Guidelines throughout the Pacific (Case 2)

set the stage for governance transformation by raising global awareness about the rights, livelihoods and dignity of small-scale fishers to a global stage. Finally, the development and communication of compelling narratives helped to lay the ground work for transformative change in all three cases.

Movement out of the preparation phase is often catalyzed by windows of opportunity. Policy negotiation can present windows of opportunity. For example, in the case of the high seas' treaty and the small-scale fisheries guidelines, global policy dialogs opened an occasion for revising existing governance structures (Table 1). Crises can also offer opportunity for change (Olsson et al., 2006). In the Seychelles, the inability of the government to pay back debt created financial incentives to consider alternative governance arrangements. Crises can also be ecological. In Chile, for example, the collapsed *loco* stocks, a critical important marine snail, helped trigger an overhaul of coastal management (Gelcich et al., 2010).

Navigating turbulent governance transitions can be supported through multi-stakeholder collaborations (Table 1). Formal consultation with more than 4000 individuals increased the legitimacy and uptake of the small-scale fisheries guidelines. In the Seychelles, a novel partnership between the Government of Seychelles, The Nature Conservancy (TNC) and the Seychelles Conservation and Climate Adaptation Trust (SeyCCAT) facilitated the establishing of a large marine protected area that stretches across one third of the Syechelles EEZ. Likewise, novel partnerships between fishers and academics in Chile, that allowed them to experiment with new management approaches, facilitated marine governance transformation (Gelcich et al., 2010).

Building resilience within new ocean governance arrangements requires contextualized institutional support for the new regime (Table 1). In the Seychelles, for example, TNC is providing monitoring and evaluation support to track the outcomes, and inform the ongoing management, of the new marine protected areas.

In addition to considering the conditions that enable transformative change, it is vital to identify points of caution (Table 2). Our cases reveal that governance transformations do not occur in a void. Rather, they occur within complex, historical policy landscapes that shape how change occurs. In the Pacific, for example, the FAO's small-scale fisheries guidelines have been received with reluctance due to insufficient consultation during the development and existing policy documents with a high degree of thematic overlap. Next, governance transformations will inevitably result in new constellations of winners and losers. In the Seychelles, the new economic development approach may in fact render the country more vulnerable to international market fluctuations and the uneven power dynamics of foreign investment and multilateral negotiation. Finally, agreement on the appropriate direction of change for governance transformations may be difficult to achieve and represents an important point for caution. In the ongoing UN negotiations for the high seas' treaty,

Table 2 Points of caution for various phases of ocean governance transformation

Points of caution
Diversity of policy landscapes within which governance transformation occurs
For example, the FAO's small-scale fisheries guidelines have been received with reluctance due to insufficient consultation during the development and existing policy documents with a high degree of thematic overlap (Case 1)
Uneven distribution of costs and benefits of governance change
For example, critics of debt-for-nature swaps have cautioned that the financial, social and ecological benefits of the new regime may be smaller than initially perceived, and that the nature of the approach may expose coastal nations to international market fluctuations and the uneven power dynamics of foreign investment and multilateral negotiation (Case 2)
Conflicting perspectives on the appropriate direction of change
For example, academics working with organizations, such as the FAO and the TNC, supported the development and communication of compelling stories in support of transformative change (Cases 1, 2 and 3)

for example, a wide range of actors are negotiating for vastly different governance approaches, ranging from strict nature reserves to sustainable use areas. Going forward, ocean governance transformations will need to account for the immense range of conditions and contexts that characterized ocean and coastal systems and be adjusted through time.

These points of caution urge us to ask: Who is driving transformational change? Who benefits? Who loses? What are the social and ecological benefits and risks of each transformative policy? Going forward, evaluation that is attentive to power dynamics and equity will help to avoid reproducing the status quo (Blythe et al., 2018). Making the political nature of governance transformations explicit and including diverse perspective across all phases may provide useful pathways towards more sustainable and equitable transformations (Blythe et al., 2018). Similarly, assessing the direction of change, the diversity of innovations that trigger change, and the distributional impacts of change may be useful guiding principles for informing transformation scholarship and practice (Leach et al., 2012).

5 Conclusions

In the wake of on-going threats to marine social-ecological systems, such as global coral reef bleaching events and persistent or rising inequality in coastal communities, realizing sustainable and equitable ocean futures will continue to present substantial governance challenges. The need to re-evaluate the rules and regulations designed to support social-ecological resilience remains paramount. To date, ad hoc anaylses have limited our capacity to systematically evaluate the conditions that enable or constrain governance transformation and the risks associated with radical governance reform. Through our analysis, we find that preparing for transformative change is enabled by the identification of a governance related challenge, growing social support for governance change and the communication of compelling narratives. Windows of opportunity can be opened through policy negotiations and social or ecological crises. Navigating governance transitions can be facilitated through multi-stakeholder collaborations and building resilience with the new governance regime is predicated on contextualized institutional support. We also find that caution should be exercised in accounting for the diversity of policy landscapes within which governance transformations occur, the uneven distribution of the costs and benefits of governance change, and conflicting perspectives on the appropriate direction of change. Continued assessment of past and on-going efforts to foster ocean governance transformation across the phases of preparation, navigating and building resilience will be critical to understand and inform transformations to more sustainability and equitable ocean futures.

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Extraordinary Governance to Avoid Extraordinary Events

Åse Johannessen and Christine Wamsler

Abstract We are in the midst of a water crisis. Scarcity, pollution and flooding are some of today's key challenges for sustainable urban development. The reasons are manifold. Preventive measures are put on the back burner, while reactive measures, siloed governance approaches and power struggles are daily business, resulting in ineffective governance. The crisis is hitting the most vulnerable urban populations the hardest and is, ultimately, a social equity issue. Against this background, we assess current water governance practice in order to identify key factors that can support social learning and enable just societal change. Taking Sweden as a critical case study, our findings highlight the potential of applying social learning theory and practice to support innovation and address the crisis. We present some key principles at three levels of resilience (socioeconomic, hazard and social-ecological), that should be considered when designing more comprehensive approaches, based on integrated learning and governance change. We conclude that an *extraordinary* governance approach is needed to support policy- and decision-makers in their efforts to reduce water-related risks and build resilience.

1 Introduction

"I have worked in water engineering all my life, but I have come to realise that the biggest challenge that we are facing are governance and learning issues, not the technology - we know the technology" – Swedish water engineer.

We are in the midst of a water crisis, and both practitioners and policymakers are increasingly forced to acknowledge that mismanagement, lack of governance and

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equity issues are at its root (Hill, 2013). However, several barriers, which go beyond developing and introducing new technological solutions, prevent the move from the individual to the collective level. In particular, social learning has been identified as a key element in change and transition processes (Berkes, Colding, & Folke, 2003; Holling, 1978; Lee, 1993). Despite this understanding, empirical studies on social learning in urban water governance remain scarce (Medema, Wals, Adamowski, 2014; Armitage, Marschke, & Plummer, 2008; Reed et al., 2010) and the few studies that indicate its positive role in the proactive transformation of water governance have not been tapped into (Johannessen et al., 2019; Huntjens et al., 2012; Madani, 2019).

In this chapter we assess current water governance practice in Sweden. The aim is to identify key factors that support social learning, address resistance and enable just societal change. We first assess current challenges. Then, we present some key principles underlying the design of more comprehensive approaches, based on integrated learning and governance change. We take Sweden as a critical case study because it is a known forerunner in ecological governance (Lundqvist, 2013) and has made clear national and international commitments to resilience building. It actively supports, for instance, the development and implementation of the Sendai Framework for Disaster Risk Reduction (United Nations Office for Disaster Risk Reduction [UNDRR], 2015), which aims to increase societal resilience, and is a generous donor to the United Nations Office for Disaster Risk Reduction (UNDRR), the body in charge of the framework. In 2016 and 2017, the Swedish International Development Cooperation Agency (Sida) donated USD 11.1 million to UNDRR, the second-biggest donor after the European Commission (USD 13.4 M) and more than Japan (USD 5.6 M) (UNDRR, 2019). The country is, therefore, a special context as important prerequisites are met for decision-makers to integrate a resilience perspective into development work in general, and water governance in particular.

The study is based on 34 semi-structured interviews, three group discussions, participatory observation and document reviews conducted during 2018-2019.

The results presented in this chapter indicate that only extraordinary governance practices can, in the long term, support disaster risk reduction and resilience measures intended to prevent and mitigate extraordinary events. We use the term *extraordinary* to denote a systemic, multilevel and integrated approach (Sect. 3) that is unprecedented, even in a country like Sweden. There is a need for a new water resilience paradigm that encompasses both persistence (of functions) and change (Chap. 1). Social learning plays an important role, not only for the needed mind shift (Folke, 2003, Chap. 1), but also in the transformation of governance structures (Pahl-Wostl, 2002). A key element is that change needs to happen not only in traditional disaster fields, but also needs to involve a multitude of other actors. Thus, it extends beyond traditional crisis management activities, such as response and recovery preparedness, to also include hazard avoidance, and hazard and vulnerability reduction across a multitude of sectors (Wamsler, 2014, Fig. 3).

2 Current Governance: The Forgotten Risks of Land and Water Use

In Sweden, and worldwide, water management plays a role in the phases or processes that make up disaster risk reduction and management (Fig. 1).

Preparedness, response and recovery phases are often referred to as crisis management. In Sweden, this activity is traditionally linked to civil defence and security policy (SOU, 2016). At national level, it falls under the mandate of the Civil Contingencies Agency (MSB). The MSB is the governmental authority responsible for developing society's capacity to prevent and manage accidents/hazards and crises (Myndigheten för samhällsskydd och beredskap [MSB], 2018). Much of the legislation that applies to the MSB is thus oriented towards crisis management (SFS, 2003; SFS, 2006). At local level, actors responsible for preparedness, response and reconstruction include municipalities, rescue, police and military services, voluntary organisations and individuals. For example, crisis management in relation to floods includes mapping flood risk, the provision of materials (e.g. sandbags) and guidelines for preparedness and response.

At government level, mandates for prevention and mitigation (Fig. 1) are mainly addressed in the recent climate adaptation strategy, which was put forward in March 2018 (Government bill, 2017). The National Board of Housing, Building and Planning was given the formal role of developing preventive and mitigation actions

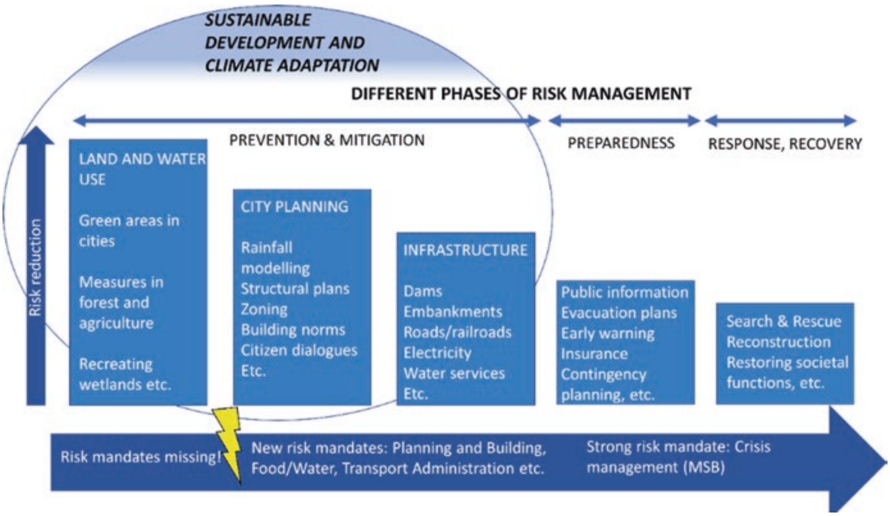

Fig. 1 Links between water and diaster risk management, sustainable development and climate adaption. The yellow "lightning" highlights the missing risk mandate for land and water use. (Adapted from WMO & GWP, 2017)

in city planning[1] (Fig. 1). This was accompanied by adjustments to the Planning and Building Act (SFS, 2010). Specifically, risk assessments were fully integrated into urban comprehensive plans and further restrictions were introduced regarding the reduction of permeability (Government bill, 2017). In terms of infrastructure (dams, roads, railways, etc.) the Swedish Transport Administration is a key actor. An ordinance (linked to the climate adaptation strategy) mandated it, together with about 20 other authorities, to work on climate adaptation. Related activities include climate and vulnerability assessments, which should be updated at least every 5 years, and help to specify the goals for climate adaptation work (SFS, 2018, Fig. 1).

Although many authorities, notably the MSB, have prevention and mitigation mandates (Fig. 1), in practice, a comprehensive approach is lacking. Such an approach would acknowledge the interlinkages between water issues that are described in widely accepted concepts such as Integrated Water Resources Management (IWRM).[2] IWRM takes the form of, for example, adopting nature- or ecosystem-based solutions,[3] integrated flood and/or drought management projects, and engaging in source-to-sea activities (United Nation Environment Programme [UNEP], 2018). In Sweden, however, institutions are resisting such approaches, as described below.

2.1 Resistance to Adopting Nature-Based Solutions

To use integrated land and water management as part of risk reduction approaches, is currently very little-used in Sweden. The European Commission's most recent evaluation of the implementation of the EU Floods Directive and the EU Water Framework Directive (Directive 2000/60/EC) recommended that the country reinforce coordination between its Flood Risk Management Plans and River Basin Management Plans (i.e., between flood risk, and water and environmental quality) (European Commission [EC], 2019a). The MSB is responsible, at national level, for the coordination of the Floods Directive, while the Swedish Agency for Marine and Water Management (SwAM) is responsible for the Water Framework Directive. Municipalities are responsible for related planning and implementation at local level.

[1] This strategy has been criticised for only focusing on the built environment and buildings – one of six working areas identified in the 2007 Climate Commission Report (SOU, 2007).

[2] The Global Water Partnership's definition of IWRM is widely accepted. It states: "IWRM is a process which promotes the co-ordinated 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" (Global Water Partnership (GWP), 2000, p. 22).

[3] The concept of nature-based solutions is relatively new, and can be defined as solutions that use nature and ecosystem services to provide economic, social and environmental benefits. Its broad scope spans other concepts, such as urban green infrastructure and ecosystem-based approaches for climate change adaptation (Wamsler et al., 2019).

The evaluation also noted that the country needs to consider making greater use of natural water retention measures in its flood risk management plans. Sweden's response is interesting: "the benefits of natural retention measures are so far uncertain when it comes to significant floods, which are the focus of the Flood Directive" (EC, 2019b, p. 10). The term "significant floods" refers probably to floods that on average occur once in 100 years. Currently, Swedish official risk maps use 100-, 200- and 10,000-year (worst-case) flood scenarios[4] as the basis for risk assessment and decision-making. However, it is not the case that these flood frequencies should be the focus of the Floods Directive, as the latter is not limited to a specific frequency. Instead, Article 1 states:

> The purpose of this Directive is to establish a framework for the assessment and management of flood risks, aiming at the reduction of the adverse consequences for human health, the environment, cultural heritage and economic activity associated with floods in the Community (European Union [EU], 2007, p. 288/29)

This Directive and its stated purpose was transposed into Swedish legislation in an ordinance (SFS, 2009), and it seems that the focus on significant floods was introduced by the MSB, due to its preoccupation with crisis management. In fact, the Floods Directive places strong emphasis on prevention and mitigation, especially from a socioeconomic perspective (EC, 2014).

However, as disasters become more prevalent and economic losses continue to grow (Centre for Research on the Epidemiology of Disasters [CRED] & UN Office for Disaster Risk Reduction [UNDRR], 2018), the discussion that is emerging at both national and international levels (notably in countries such as Norway and the United Kingdom) increasingly tends to focus on rare events, while the main socioeconomic costs, may in fact, be due to events that occur more frequently (Wamsler & Johannessen, 2020). Costs related to smaller floods that occur every 10, 20 or 50 years should provide a clear incentive to invest in mitigation measures, such as the use of wetlands or other nature-based solutions (Fig. 2). Such multipurpose measures (e.g. Haase, 2017; Woroniecki, Wamsler, & Boyd, 2019) can have many synergetic effects on society, the environment and the economy. These include, for example, sustaining critical ecosystems, mitigating leakage of nutrients and eutrophication, reducing costs for (and possibly empowering) households and farmers, while also reducing critical infrastructure costs (EC, 2014; Haase, 2017; Hardiman, 2007; Woroniecki et al., 2019).

In this context, cost–benefit analyses are a particularly useful decision-making tool. However, in Sweden, as in many other countries, data is lacking. Basic information regarding losses and damage from both large and smaller floods, or other natural hazards, is in many cases not recorded. On the other hand, there is some data available at international, regional and national levels through initiatives and

[4] A 100-year flood is generally understood to refer to a flood that has a probability of occurring, on average, once every 100 years. The term has been criticized for being misleading as, in fact, it refers to a flood that has a 1% chance of happening in any given year. A 100-year flood can occur 2 years in a row, although it is very unlikely.

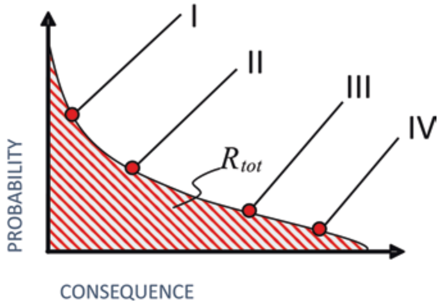

Fig. 2 Flood scenario modelling gives the total risk, Rtot, as the total surface of the graph. I: Level for a 100-year flood; II: Level for a 50-year flood; III: Level for a 20-year flood; IV: Level for a 10-year flood. (Rosén & Nimmermark, 2018)

international loss databases, such as EM-DAT, Desinventar and Re-insurance. At EU level, a key priority is to improve the disaster management knowledge base, by developing disaster loss databases (cf. the EU Disaster Prevention Framework, reported in the EU Council's conclusions of 30 November 2009). A European perspective is particularly important in understanding and managing transboundary effects of disasters, together with linkages to climate change and the contribution to international dimensions (EC, 2013).

In Sweden, there is a national database for natural hazards.[5] However, it only records extreme events, and loss and damage data needed for municipal water and risk planning is not available. Not only municipalities are concerned. A representative from the Swedish Transport Administration states:

> We have no clue how often a road is closed off because of floods and how much it costs us. We don't know why it happens and how we can avoid it next time. When you work with traffic safety, you focus on the questions: Why does the accident occur? How do we prevent the next one? This thinking is not at all present when it comes to natural hazards. (Wamsler & Johannessen, 2020, p. 4)

These observations highlight what the 2018 Katowice Climate Change Conference recognized: the need to regularly report on climate-related losses, and to assess information about losses and damage. Another factor is researchers' lack of awareness of policy processes, which has slowed progress (Scientific Committee, 2019).

2.2 Lack of Integrated Flood and/or Drought Management Projects

Drought and water scarcity are closely linked to flooding. Drought can be defined according to meteorological, hydrological, agricultural or socioeconomic criteria; here the first two are most relevant. *Meteorological drought* is defined as a deficiency of precipitation compared to expected or normal amounts over an extended

[5] See MSB database for natural hazards: https://www.msb.se/naturolycksdatabas

period of time. *Hydrological drought* occurs when the supply of surface and subsurface water is insufficient to meet normal and specific water demands (UNDRR, 2005). *Water scarcity* can refer to scarcity in availability due to a physical shortage, or scarcity in access due to the failure of institutions to ensure a regular supply, or a lack of adequate infrastructure (United Nations Water [UN-Water], 2019). Simply stated, it occurs when demand for freshwater exceeds supply in a specified domain (Food and Agriculture Organization of the United Nations [FAO], 2012). Water managers can both influence and address shortages; for instance, land use can influence river basin flows and exacerbate retention problems (Haase, 2017). Therefore, a comprehensive mandate to manage floods should also include a mandate to manage water scarcity and drought (Grobicki, MacLeod, & Pischke, 2015).

In Sweden, however, there is no legislation or mandated authority that explicitly addresses risk reduction in land and water management to prevent water scarcity (Wamsler & Johannessen, 2020). The issue was highlighted in a workshop that brought together all Swedish water authorities in August 2018. The workshop was convened to reflect on the hot and dry summer of 2018, and to share the results of several governmental assignments that were conducted in response to the water scarcity in south-east Sweden in 2016 and 2017. For example, in 2017, the SwAM investigated the possibilities, preconditions and consequences of introducing crisis management methods during a period of acute scarcity through changes in legislation and prioritising use scenarios (Hogdin, Gustafsson, Liveland, & Sorby, 2018). The Agency concluded that this was currently not feasible, not least because many water outtakes in Sweden are not known, which makes it difficult to assess potential water use reductions. A first step would instead be to map available water resources and, in areas where resources are limited, take measures to make better use of water. However, it is too late to take such actions when scarcity is already a fact.

The SwAM suggested that more systematic and coordinated ways of working were needed to prevent and mitigate issues of scarcity. A crucial element, in this context, is planning and climate adaptation that involves all relevant actors and sectors in society, and making better use of existing resources (Hogdin et al., 2018). This example illustrates that crisis management in times of drought also relies upon effective prevention efforts. One of the workshop's recommendations was to make better use of ecosystem services in building and maintaining water courses. In this context, the restoration and recreation of wetlands and water in the landscape was seen as a key way to prevent and mitigate the effects of drought (Carlzon et al. 2018).

2.3 The Source-to-Sea Approach: Water Quality Without Water Quantity

Water quality and quantity are intrinsically linked in the natural world. For example, floods, in nature, are a crucial ecological dynamic that involves both water quantity and quality processes (Haase, 2017). Also, floodwater can contain many pollutants, for example industrial waste or from sewage treatment facilities that release untreated wastewater when capacity is reached (Smittskyddsinstitutet, 2008).

Despite this situation, the Swedish governance approach often separates quality and quantity. For example, the so-called *source-to-sea approach* adopted by the SwAM (together with actors such as the Swedish Environmental Protection Agency (EPA), water authorities and county administration boards), highlights that upstream pressures can have downstream effects, and that there is a need to coordinate efforts to manage freshwater and oceans. However, the approach only concerns water quality, and not quantity (i.e., flood management). Consequently, the SwAM and related actors promote the recreation of wetlands and river meanders mainly based on a water quality and environmental rationale. Floods are often mentioned by these agencies in the context of wetland multifunctionality, and related guidelines are emerging from regional authorities (e.g. Länsstyrelsen i Västra Götalands län, 2018), but these are not significantly applied as flood risk reducing practices in Sweden.[6] This relates to the fact that promoting flood risk management is not the formal task or mandate of these organisations. This is also reflected in the Environmental Code (SFS, 1998), which primarily focuses on water quality and threats from pollution.

2.4 …and the Municipal Planning Monopoly that Undermines River Basin Planning

In Sweden, an important aspect of land and water management is the municipal planning monopoly, which encompasses flood risk planning and management, and securing the drinking water supply. However, river basins can cross several municipal boundaries, and changes in upstream land use can increase flows to downstream areas. One example is paving urban areas without creating adequate infiltration, storage or drainage. This increases runoff and leads to flooding in downstream areas (Voskamp & Van de Ven, 2015; Government bill, 2017). There are no provisions for river basin management, which goes against established water governance and management principles (GWP, 2000; World Meteorological Organization [WMO], 2009) and the EU Floods Directive (2007/60/EC). This makes it difficult to plan upstream measures for water courses, or forested or agricultural land if these areas are located in a different municipality (Johannessen & Hahn, 2013). The potential consequences impact downstream urban areas, as a function of factors such as topography, geology and hydrology (Fig. 3). Likewise, drinking water sources, which the municipality is supposed to protect, are affected by inflows from surrounding river basins and the land use practices of neighbouring municipalities.

[6] One of the five Flood Risk Management Plans assessed by the European Commission contains an objective that refers to the use of wetlands for water retention (EC, 2019b).

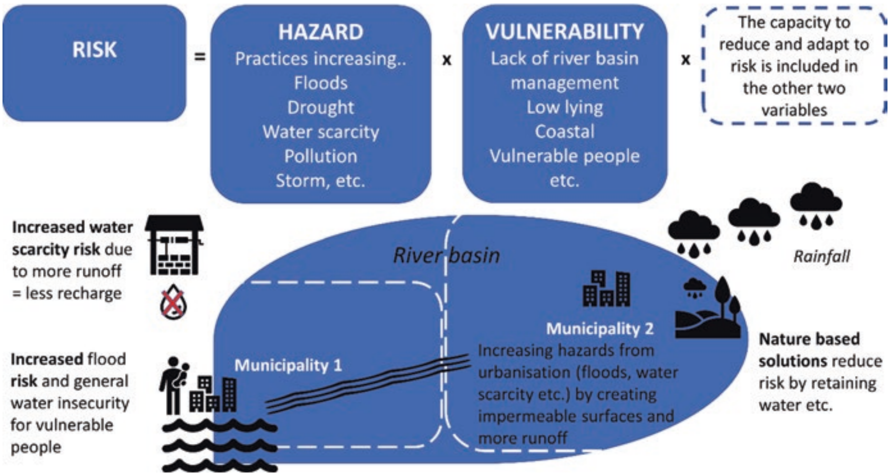

Fig. 3 The creation of risk through increasing hazard and vulnerability (after Wamsler, 2014). For example, practices that increase flooding and water scarcity, and a lack of river basin management increase risk and water insecurity, especially for vulnerable populations

2.5 One out of Three Drinking Water Sources Does Not Have Formal Protection

The supply of drinking water is also at risk due to a lack of protection and monitoring. It is recommended under the EU Water Framework Directive, and the Swedish national environmental quality objectives, that public water sources that supply over 50 people should be protected (EC Directive 2000/60/EC; Swedish Environmental Protection Agency [EPA], 2018). However, a survey of all Swedish County Administrative Boards shows that one out of three sources has no protection: access is not secured, and no measures are in place to protect them from pollution by, for example, restricting the use of pesticides and petroleum products. In addition, almost 40% of non-protected sources are in municipalities that have had problems with their water supply in the past few years. Moreover, about half of protected sources were protected before 1998, when the Environmental Code was introduced, which means any protection is likely to be outdated. Furthermore, a wide range of regulatory exceptions reduce the quality or extension of current protection measures (Värjö, 2019).

2.6 Confusing, Parallel Policy Processes

Another challenge is siloed policy processes introduced following the Paris Agreement, the Agenda 2030 Sustainable Development Goals (SDGs) and the Sendai Framework for Disaster Risk Reduction (UNDRR, 2015). Although intended to function as three, interlinked pillars for resilience building, the implementation of the Sendai Framework in Sweden has lagged behind. As a result, recent risk reduction policies are mainly due to the country's climate adaptation strategy, and are thus linked to climate change and not, *per se*, to risks caused by unsustainable development. For example, the new mandates for risk reduction delegated to the Swedish transport sector and spatial planning authorities were recently created as a result of the country's climate adaptation strategy, and not in relation to an overall risk reduction strategy aimed at coordinating different risk reducing efforts. The resulting legislation is evidence of the influence of climate change experts in its preparation. For example, in the changes to the PBL only references are made to "*climate*-related floods", while not all floods are necessarily climate related (Wamsler & Johannessen, 2020) and can be closely related to urban and rural development (Sect. 2.4 & Fig. 3). Development in flood-prone areas is a typical example of an action that increases flood risk (Ran & Nedovic-Budic, 2016).

3 Building Extraordinary Governance

In the previous sections, we described current water governance challenges with a special focus on Sweden. On this basis, we now present some principles for building *extraordinary* governance, i.e. approaches to bring about more systemic, multilevel, integrated learning and governance change. But first, we will describe some basic aspects of social learning theory.

3.1 Social Learning Theory

Social learning theories often describe learning as multiple, iterative cycles of deliberation and engagement (Kolb, 1984). The so-called *learning loop framework* integrates these theories and divides learning processes into three loops, which denote the degree to which learning promotes transformational change in management strategies (Argyris & Schön, 1996; Keen, Bruck, & Dyball, 2005). In practice, *single loop learning* is by far the most common, and is based on error detection and correction by the addition of new knowledge or competencies, without changing underlying mental models or assumptions. In this mode, the social group or organisation engaged in the process carries on its activities and policies that seek to achieve its present objectives, with minor adjustments (Argyris & Schön, 1996). Studies have shown that single loop learning can, however, be a barrier to deeper learning as it builds institutions that invest resources and seek prestige from learning within a specific domain, and resist changes (Johannessen et al., 2019).

Learning at a deeper level involves reflecting on underlying assumptions, and is thus more transformative. This type of learning is called *double loop learning.* It addresses the question: Are we doing and addressing the right things? Learning outcomes concern, for example, more comprehensive changes to the organisation's knowledge base, and the establishment of new objectives or policies (Argyris & Schön, 1996). It is often accompanied by a process in which existing mental models are broken down or reframed and, with it, our understanding of how the world works and how we take action (Senge, 1990).

Triple loop learning has the highest transformative potential. It is concerned with why we learn the way we learn (Medema et al., 2014). For example, what norms, values and paradigms guide action, and how can we address and change them? This level of learning often involves changes to the governance and knowledge infrastructure, in order to bring together the relevant actors. If a relevant part or unit is missing, learning cannot capture or address the full diversity of issues and associated power dilemmas (Flood & Romm, 1996).

In the context of water management, transformation through social learning also requires learning that links three resilience levels (Johannessen & Wamsler, 2017). These are:

- Social-ecological systems' resilience
- Hazard resilience
- Socioeconomic resilience

These resilience levels are nested and represent three different foci: the type of system; the type of disturbance; and the type of approach needed to address water related risks. Learning loops are found at all three levels, with different implications for change and transformation in practice and behaviour that, ultimately, feeds back to the resilience level (Fig. 4).

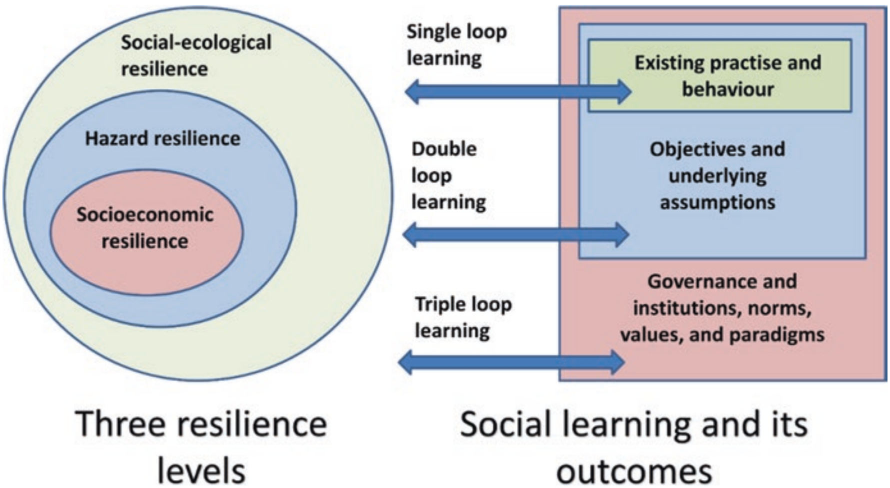

Fig. 4 Social learning can occur at different levels in a system, which has implications for resilience and vice versa. (Johannessen & Wamsler, 2017)

3.2 Social–Ecological Systems' Resilience

Social-ecological systems' resilience refers to resilience to disturbances to the functioning of social-ecological systems. Such disturbances are often related to unsustainable development processes such as unsustainable resource extraction, which can cause longer-term and larger-scale risk (Johannessen & Wamsler, 2017).

To support social ecological resilience, knowledge on the complexity of natural resources management is needed, including adoption of IWRM. This would supplement the current crisis management approach with more long-term, mitigative and preventive planning and risk reduction. Many of the examples given in the previous section illustrate inadequate social–ecological systems' resilience, notably a lack of prevention and mitigation at larger geographical scales. Improvement requires management at the appropriate scale (or fit) – a recommendation that has been repeated for many years (Folke, Pritchard, Berkes, Colding, & Svedin, 1998; Folke, Pritchard, Berkes, Colding, & Svedin, 2007; Galaz, Olsson, Hahn, Folke, & Svedin, 2008). It harnesses systems dynamics and avoids unpleasant surprises, an aspect that is often emphasised in resilience management but not, so far, in IWRM (see also Chap. 1). Accordingly, the following principles are key to social-ecological resilience in Sweden, and elsewhere, and are presented in the following sub-sections:

- Implement river basin management of floods
- Integrate flood and water scarcity management
- Integrate flood risk with water quality management
- Prioritise and support the implementation of nature-based solutions, where possible

3.2.1 Implement River Basin Management of Floods

The appropriate level for water management is, generally, the river basin (WMO, 2009; GWP, 2000). In Sweden, this needs to be applied to flood risk management in the same way it is already applied to water quality management. River basin management plans are currently a management tool under the EU Water Framework Directive and should, ideally, be fully integrated with flood management plans. Such coordination is also an EU requirement (EC, 2007, article 9). However, in Sweden, as in many other countries, flood risk is largely identified at municipal level, which makes coordination difficult (Johannessen & Hahn, 2013).

In this context, the Dutch water authority model that coordinate activities in river basins, with origins in the thirteenth century, is seen as part of a global reference by actors such as the OECD (Organisation for Economic Co-operation and Development [OECD], 2014). Sweden would thus be well-advised to consider adopting such a model. The Netherlands has 21 River Basin authorities. These autonomous, fully-fledged entities operate alongside national, provincial and local governments, that are also tasked with flood defence, water quality and quantity issues (Dutch Water Authorities, 2017). Sweden is about ten times bigger than the Netherlands, with currently five water authorities that are each administered by a County Administration

Board (CAB). These numbers suggest that Sweden could probably divide their five water authorities into smaller units. Their administration by the five CABs was once a subject of debate, and the final decision was based on the argument that these bodies already dealt with similar issues (SOU, 2002). However, some municipalities argue that the CABs dual role of reviewer/investigator and providing advice to municipalities on their (e.g. spatial planning) work, makes their advisory role more challenging (Swedish EPA, 2013).

3.2.2 Integrate Flood and Water Scarcity Management

Water scarcity and flood risk are intrinsically linked, as both are affected by land and water use decisions (Estrela & Vargas, 2012). For example, digging canals to improve transport and drainage can contribute to scarcity as the water-holding capacity of the landscape is reduced (Haase, 2017). Despite this fact, when a flood occurs, re-investment and new investment target flood mitigation, seldom considers how actions could also address future drought and water scarcity, and vice versa (United Nations University International Human Dimensions Programme on Global Environmental Change [UNU-IHDP], 2014). It is clear that there is a need to break down policy silos between these two linked areas (Grobicki et al., 2015). In Sect. 2.2, we noted that Sweden lacks an authority that has an overall mandate to manage drought or scarcity. However, key actors include the Ministry of the Environment, the EPA, the SwAM, the Meteorological and Hydrological Institute (SMHI), the Geological Survey (SGU) and the five water authorities. It would be clearly beneficial to give any of these institutions a mandate to deal with this matter, and improve integration between water quality and flood management. A broader-scale initiative may also be required. For instance, in the Netherlands, a national Delta Programme was created. This sets out plans to protect the country from flooding, mitigate the impact of extreme weather events, and secure supplies of freshwater (Government of the Netherlands, 2019).

3.2.3 Integrate Flood Risk with Water Quality Management

Integrating water quantity and quality management can create synergies that improve the wellbeing (and even existence) of society. For example, ensuring water quality is a prerequisite for the sustainable provision of drinking water and, thus, crucial for food provision and public health. Here again, action is needed at river basin level (Sect. 2.4) and the five water authorities could play a more important role. A related example comes (again) from the Dutch model, where regional authorities are responsible for both water quality, quantity, and flood defence (Dutch Water Authorities, 2017; OECD, 2014). Furthermore, local groups that are active in water protection can play an important role in local capacity building. For example, the Basque region of Spain has facilitated a process aimed at engaging different stakeholders in monitoring the quality and quantity of water resources which has generated new perspectives (Osbeck et al., 2013). In general, better coordination between – not only water quality and quantity management (e.g. risks) – but also the areas of climate adaptation and spatial planning, is needed to provide broader synergies. Such synergies are needed to achieve the societal aims embodied in the SDGs, and respond to the ecological ambitions of European water policies (Wuijts, Driessen, & van Rijswick, 2018).

3.2.4 Prioritise and Support the Implementation of Nature-Based Solutions, Where Possible

Nature-based solutions have a high potential for multifunctionality, being able to reduce water-related risks (floods, scarcity), support climate adaptation and biodiversity conservation, improve water quality, address social issues such as recreation and, possibly, enhance equity and power-related problems (Bouleau & Pont, 2015; Carter & White, 2012; Haase, 2017; Voskamp & Van de Ven, 2015; Woroniecki et al., 2019). Although not always the best solution, they should be prioritised where possible as they are not only multipurpose and flexible, but represent a cost-effective alternative to other types of approaches. In Sweden, the 2019 budget supports nature-based solutions by earmarking more money to restore wetlands and mitigate eutrophication (Swedish Government, 2019). Here we note that their benefit to risk management is not mentioned (Swedish Government, 2019). It is notable that the integration of nature-based solutions into governance (in general) and water governance (in particular) remains very limited (Wamsler et al., 2019a, b). Also making them an integral part of a risk strategy would appear to be important. Currently, there are many barriers slowing their implementation (Wamsler et al., 2020). Financing is a particular problem, as interventions are often viewed from a sectoral perspective, rather than taking a whole system approach. Therefore, cross-sectoral interventions, based on cost-sharing, could provide a much-needed incentive and sufficient funding (Sect. 3.3.3). Also, prioritisation has played a key role in success stories (Wamsler et al., 2020).

All of the areas outlined in Sections 3.2.1, 3.2.3 and 3.2.4 require social learning, leading to a shift in focus from crisis management to risk reduction, with a focus on long-term mitigative and preventive measures. For that to happen, all of the actors involved in sustainable development must be engaged and given a stronger mandate. For example, actors such as the Ministry of Environment, the EPA, the SwAM, the SMHI, the SGU, water authorities, and CABs, all have, to varying degrees, an understanding of water as a natural resource, its complexity and the need for integrated and systemic management. Their contributions to the 'knowledge infrastructure' needed for disaster risk reduction in land and water management would be a welcome complement to the MSB's current focus on crisis management and major floods.

Consequently, it is clear that triple loop learning is needed (Sect. 3.1). Here, the governance and management systems need to be transformed to accommodate this knowledge integration. Relevant authorities need to be given a formal mandate to reduce risk in land and water management by adopting an approach that integrates, for instance, flood and drought management. For this to happen, coordination is not sufficient. Instead, knowledge on water quality needs to be incorporated into early, strategic decision making on flood management – for example, by making a case for nature-based solutions that could also address important water quality risks. For cities, this would also require strengthening the role of water in strategic decision making, especially related to spatial planning (Hurlimann & Wilson, 2018). Some urban water providers have already taken initiatives (e.g. "together we make space for water" by VA Syd (VA-Syd, 2019), recognizing the need to broaden the traditional scope of water issues. On a broader, regional or national scale, this would require that floods and water quality are governed by the same entity/department. This proposal is supported by the fact that the EU Floods Directive and the Water Framework Directive are governed by the same authority in most countries (EC, 2014). Such a move could identify synergies and conflicts, help to synchronise measures, support the pooling of resources and instruments, and avoid negative effects (Evers, 2016). In terms of legislative change, there is also a need for improved integration and coordination to better serve both social–ecological and hazard resilience. For example, the Swedish Environmental Code (SFS, 1998) says very little about risks, but a lot about the environment (and nature-based solutions). At the same time, the Planning and Building Act (SFS, 2010) makes reference to climate-related hazards such as floods but has less to say about the environment (and nature-based solutions).

3.3 Hazard Resilience

Hazard resilience refers to societal resilience to so-called natural hazards. These hazards can lead to rapid (e.g. floods) and slow onset disasters (e.g. drought), with short- and/or long-term societal impacts (Johannessen & Wamsler, 2017). To build hazard resilience, non-crisis management actors working in water and land management also need to learn from risk management methods. In this context, the following principles are key to hazard resilience in Sweden, and elsewhere, and are addressed in the following sections:

- Increase knowledge and awareness of the need for safe-fail approaches
- Monitor, collect and analyse data on damage from natural and man-made hazard events
- Apply holistic evaluation methods and cost-sharing mechanisms
- Introduce stricter rules for regulating risks

3.3.1 Increase Knowledge and Awareness of the Need for Safe-Fail Approaches

In response to the need to include risk in planning, spatial planners need to understand the inherent uncertainties and challenges related to risk mapping and reduction to ensure hazard resilience (Björkman, 2014). This would allow them to take a more precautionary approach and prioritise a *safe-fail* (failing is safe/failure is permitted) mode where possible. The safe-fail approach contrasts with the *fail-safe* belief that, for example, a structural protection will never fail, or floods will never extend beyond areas known to be at risk. Illustrations of the safe-fail approach are avoiding building in flood plains or low-lying areas at flood risk, not placing vulnerable objects behind structural defences (as they can break), building houses on stilts, or installing a flood-proof cellar and ground floor. In this context, the Netherlands has, following double and triple loop learning processes, adopted a "living with water" approach through the Room for the River Programme.[7] Here, safe-fail systems support flood preparedness, non-structural mitigation measures and urban design, rather than simply focusing on flood protection (Huntjens et al., 2012). Although nature-based solutions might not be able to provide 100% protection, this might not be essential if there is a comprehensive approach that encompasses a variety of risk-reducing measures (Fig. 3 & Section 1).

3.3.2 Monitor, Collect and Analyse Data on Damage from Natural and Man-Made Hazard Events

As described in Sect. 2.1, Sweden lacks a database to record loss and damage due to natural and man-made hazards. This makes it impossible to run accurate cost–benefit analyses that could help to assess effective interventions; notably to compare damage from less-extreme but more-frequent events, with that due to less-frequent but more-extreme events. An interesting example comes from Norway, where a pilot public–private partnership was implemented in ten municipalities from 2013 to 2015. The aim was to understand what, exactly, was at risk and where these risks were located to, ultimately, improve decision-making (Brevik, Aall, & Rød, 2014). The initiative was launched by an insurance actor that provided local disaster loss data to municipalities. It resulted in increased collaboration between planners and technical staff within municipalities. It also led to new knowledge about previously unknown risk areas, and an improved understanding of how climate change affects society (Brevik et al., 2014).

The development of a database of loss and damage due to natural hazards at a spatial scale that is relevant to municipal and regional planning authorities could support important triple and double loop learning processes in areas where different professionals have not previously communicated. Risk, risk objects and risk perception are socially constructed (Douglas & Wildavsky, 1983; Tierney, 1994); therefore, the collection and modelling of data (hydrological flows, environmental quality, water outtakes, socioeconomic loss and damage, etc.) at an appropriate spatial scale, is critical to challenge current understandings, assumptions and, ultimately, provide decision support.

[7] Room for the River Programme website: https://www.ruimtevoorderivier.nl/english/

3.3.3 Apply Holistic Evaluation Methods and Cost-Sharing Mechanisms

Research illustrates that innovation adoption tends to be triggered by extreme events (Johannessen et al., 2019). However, it can also be supported by win-wins that improve the effectiveness of day-to-day operations (i.e., socioeconomic resilience) and, at the same time, ensure that key functions can continue during hazard events (Johannessen & Wamsler, 2017). In other words, new innovations should not be more costly than traditional measures. Taking nature-based solutions as an example, although these innovations are not necessarily more expensive, the financial system (e.g. budgeting) and the organisation are constructed around traditional solutions, which makes their adoption challenging. To compare possible alternatives, cost–benefit and life cycle analyses can be helpful, but they are not sufficient. In addition, changes in the conception of nature, budget allocation and cost-sharing methods need to be adopted across multiple municipal departments, sectors and actors.

Cost-sharing mechanisms are justified by the fact that nature-based solutions provide a range of services and benefits to society; notably better health, increased biodiversity and pollution mitigation. However, they often require more space and maintenance, which makes them a less attractive choice in the initial phases of traditional planning (Wihlborg, Sörensen, Alkan, & Olsson, 2019; Wamsler et al., 2020). Thus, financing and associated power struggles, continue to dominate many decisions about which measures to implement (Wamsler et al., 2016). This is also the reason why solutions such as those identified in Augustenborg, Malmö (Fig. 5), have not been implemented systematically in other areas of Sweden. To address underlying root causes, it is also important to challenge business-as-usual, and change current assumptions, paradigms and mindsets through capacity development and awareness-raising. This involves overcoming resistance to change in working cultures, where people are used to doing certain things in a certain way. In this context, social learning is key to addressing underlying causes (Sect. 3.1).

3.3.4 Introduce Stricter Rules for Regulating Risks

In Sweden, current risks to drinking water sources have far-reaching, serious consequences in the long term, and there is a need for stricter rules and clearer priorities at both national and municipal levels. For example, mandatory, rather than voluntary government action would require triple loop learning. A change in strategy would move water security up the municipal agenda, shifting objectives and underlying assumptions, would require double loop learning. Such measures could also help to manage conflicting goals at municipal level—for example, the need for short-term economic benefits versus the need to secure resources that are vital for human and planetary wellbeing. Without stricter regulations and central directives, elected local officials often find it difficult to establish suitable priorities, and need to give in to short-term agendas. Nevertheless, there are some indications that things are moving in the right direction. For instance, the Swedish government recently

Fig. 5 Open stormwater drainage in Augustenborg, a social housing area in Malmö, Sweden (photo by Åse Johannessen)

pointed out that environmental monitoring is critical when developing efficient measures to protect water courses, and provided additional funds for this purpose in the 2019 budget (Swedish Government, 2019).

3.4 Socioeconomic Resilience

Socioeconomic resilience refers to resilience to the disturbances to the functioning of water services, and the entities that manage and govern them. Such disturbances are linked to socioeconomic, political, and/or institutional structures, and associated governance mechanisms. Examples include corruption; power and equity issues; capacity gaps; economic disruption and an increase in bad debt (Johannessen & Wamsler, 2017). They are intrinsically linked to socioeconomic resilience, and concern stakeholders' capacity to drive developments in a more (or less) sustainable direction, seen in capacity development, improved technical knowledge and science–policy integration. Accordingly, in order to build socioeconomic resilience all actors relevant to water and land management need to increase such capacity. Without such a capacity it will then also be more challenging to build a system that can govern and manage the other two levels of resilience (Sections 3.2 and 3.3). We argue that the following principles are key to socioeconomic resilience in Sweden, and elsewhere:

- Build capacity to better understand the multiple risk nexus and dynamics
- Foster applied research that supports policy, implementation and understanding of the multiple risk nexus
- Promote equitable approaches

3.4.1 Build Capacity to Better Understand the Multiple Risk Nexus and Dynamics

Risk emerges from a complex cocktail of factors; it is a combination of pressures that emerge from issues such as unsustainable development, climate change, environmental threats and degradation. These, in turn, increase exposure, vulnerability and the frequency/intensity of hazards (Peduzzi, 2019, Fig. 3). Bringing together the disaster risk reduction, climate adaptation and sustainable development communities of practice is, therefore, key to creating synergies and avoiding the duplication of effort. This observation is advocated by many of the actors engaged in the development of parallel policies and procedures (UNDRR, 2018).

Streamlining related local processes would help considerably. When taking a local approach to resilience it is, however, important to consider all three types of resilience. This is because resilience at the socioeconomic level does not automatically mean resilience at the hazard or social-ecological level. For example, improvements to the delivery of urban water to communities—which can be equated with "achieving resilience"—can lead to the pollution and salinization of water resources at a broader social–ecological scale (for example, because of open access results in excessive use) if the other resilience levels are not considered (Johannessen et al., 2019).

3.4.2 Foster Applied Research That Supports Policy, Implementation and Understanding of the Multiple Risk Nexus

Coordinated efforts to increase capacity across different actors and sectors is crucial in building socioeconomic resilience. This should be supported by both governmental agencies and academia. In many countries, academic education and research are often too distant from on-the-ground challenges and needs (Johannessen & Wamsler, 2017), and Sweden is no exception. Applied research should address this gap by fostering the required single, double and triple loop learning. For example, by supporting policy development, the implementation and understanding of the multiple risk nexus, and the associated (need to change) underlying mindsets and assumptions.

3.4.3 Promote Equitable Approaches

The inability to govern social-ecological or hazard resilience has inevitable consequences for socioeconomic resilience, in the form of increased societal and individual risk. In Sweden, the inability to govern at river basin scale contributes, for instance, to increasing risks for individuals for potential loss and damage (Government bill, 2017). It tends to be the most vulnerable and marginalised members of the community who are disproportionally hit by a lack of adequate governance. This chapter was written in 2019, just after storm Idai caused devastating flooding, displacement, death and wide-scale destruction in Mozambique, Zimbabwe and Malawi. Similarly, in Sweden, flooding has particularly negative health and psychological impacts on the vulnerable; where the poor, the elderly, children and immigrants are likely to be among the people most affected (Grahn, Nyberg, & Blumenthal, 2014). In order to support these vulnerable groups (and citizens in general), it is vital that they are provided with information about how governance and management at the other resilience levels affect them. In addition, citizen dialogue initiatives, community networks and involvement are increasingly providing transparent mechanisms for citizens to build their own capacity and take action. One example is YIMBY (Johansson, 2019) advocating for dense, varied and integrated urban development. This grassroots network operates in four Swedish cities and is engaging with city planning and development.

Experience from work at community level shows that a combination of local capacity development, local leadership, increased ownership and empowerment can be important levers in supporting vulnerable communities (Johannessen et al., 2019). They allow communities to build their collective strength and self-confidence and develop relevant local initiatives that support resilience including the protection of common resources (Kar, 2011). However, people who support communities and, particularly, vulnerable groups must understand how to manage power struggles and behavioural change, mobilize capacities and be able to address the underlying assumptions that exist within the wider society and systems (Twigg, 2009). Developing joint actions that provide solutions and systems to meet shared goals can benefit everyone. Such joint actions—for example, between policy-makers or service providers, and community members (e.g. resource users)—also open up opportunities for power asymmetries to be addressed (or reproduced). This can either lead to resistance and unwillingness to cooperate, or citizens who are readier to work together. A final observation is that it is important to pay attention to the design of meeting spaces, as this can shape the degree to which policy approaches are accepted, and respond to the needs of the most vulnerable members of society (Wamsler & Raggers, 2018).

4 Conclusions

Our analysis of current water governance practice in Sweden as a critical case led to the identification of a set of key principles for creating more comprehensive approaches, based on integrated learning and socially just governance. The identified principles address the three levels of resilience: social-ecological, hazard and socioeconomic.

With respect to ***social-ecological resilience***, our study suggests that knowledge from land and water management, and communities of practice actively working on the Sendai Framework, Agenda 2030, the SDGs, and climate adaptation should supplement the current focus on crisis management, in order to reflect the complex nature of natural resources and water management.[8] Indeed, one of the challenges to the implementation of the Sendai Framework for Disaster Risk Reduction and related water governance, is that the mandate for risk reduction and resilience building is limited and, by default, is translated into crisis management. Instead, responsibility needs to be spread across a broader range of institutions; for example, those with knowledge of land and water management, spatial planning, environmental planning and infrastructure development. Margareta Wahlström, former UN Special Representative for the Secretary General of UNDRR stated that: "*Many countries feel that they have disaster risk reduction plans, but very often they are preparedness plans*" (Wamsler & Johannessen, 2020, p. 4). Although the UNDRR is aware of this issue and encourages mainstreaming across sectors and fields, the fundamental challenge is that national agencies (such as the MSB) do not have an overarching mandate. Consequently, mainstreaming needs to happen on a voluntary basis.

[8] This includes IWRM, which can support prevention and mitigation (i.e., risk reduction) in land use management.

The key, guiding principles to support social–ecological resilience identified and presented in this chapter are:

- Implement river basin management of floods
- Integrate flood and water scarcity management
- Integrate flood risk with water quality management
- Prioritise and support the implementation of nature-based solutions, where possible

With respect to ***hazard resilience***, we argue that knowledge from land and water management, along with communities of practice actively working on Agenda 2030, the SDGs, and climate adaptation need to adopt risk management approaches and methods. In this chapter, we present the following guiding principles to support hazard resilience:

- Increase knowledge and awareness of the need for safe-fail approaches
- Monitor, collect and analyse data on damage from natural and man-made hazard events
- Apply holistic evaluation methods and cost-sharing mechanisms
- Introduce stricter rules for regulating risks

Finally, turning to ***socioeconomic resilience***, we argue that there is a need to improve stakeholders' capacity to drive developments in a more (or less) sustainable direction. This includes technical knowledge, science—policy and science—practice integration, and associated social learning for all actors engaged in water and land management. Furthermore, there is a need to understand dependencies with other types of resilience, as these will, ultimately, affect socioeconomic resilience. Strengthening citizen involvement is a crucial way to overcome power struggles between specific interests and shared resources. In this chapter, we identify the following principles to support socioeconomic resilience:

- Build capacity to better understand the multiple risk nexus and dynamics
- Foster applied research that supports policy, implementation and understanding of the multiple risk nexus
- Promote equitable approaches

Actively paying attention to the "knowledge infrastructure"—which brings together the relevant actors (including the marginalised) with different perspectives—is at the core of the principles presented here. Our aim is to support social learning that leads to just societal change and resilience. Finally, we note that the process of building such a knowledge infrastructure requires strong policy support. This could take the form of a national programme for comprehensive water governance; such a programme would be a vehicle for the principles we present, and inform and link relevant strategies, policies and actors.

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Part IV
Conclusion

Charting a Course for Management and Governance Dimensions of Water Resilience

Julia Baird

Abstract This concluding chapter highlights cross-cutting messages and future research needs from the contributions to the volume. It is organized into two sections: the first synthesizes and reflects on the main messages: the nature of water resilience as a continuously negotiated construct; recognition that we are operating within a legacy of water management and governance approaches; the importance of time; and, a recognized preference for water governance where there are multiple actors in a combination of top-down and bottom-up approaches. The second section synthesizes future research needs, charting a course for management- and governance-focused water resilience research where further attention is needed to: water governance levels and interactions; power as a critical consideration; and, contributions of social learning to resilience. Engaging in both reflexivity and in looking forward identify these synthesized contributions from this volume to a water resilience research agenda.

1 Introduction

Alarm bells are ringing all around us. Reports are being produced—seemingly by the week—describing the global water crisis in terms of devastating droughts, more severe and frequent floods, and extensive and sometimes deadly pollution of freshwater and our oceans. The impacts are far-reaching and devastating to human and natural systems. There are concerns that water related conflicts will increase over time (Petersen-Perlman, Veilleux & Wolf, 2017). These water issues are intertwined with climate change and its many all-encompassing impacts. Overall warming of the planet over the past century of 1 °C has caused extensive ecological and social consequences, and scientists across the globe have issued serious warnings about

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the devastating impacts if transformational change is not undertaken (de Coninck et al., 2018; Rockström, 2015). We are operating in the Anthropocene and it is clear that business-as-usual is not an option. It is also clear that *how* we move forward is critical. We need an approach that recognizes the complex, dynamic and uncertain nature of linked social-ecological systems. We need an approach that has flexibility to be appropriate in a range of contexts. Water resilience is such an approach and offers a path forward in these times of change.

There is a long history of water management and governance research allied with the concept of water resilience. As set out in the introduction of this volume, water governance emerged as a critical concern in the first years of the twenty-first century. Those concerns gave rise to a transition from 'government' to 'governance' (de Loë et al., 2009), the rise of hybrid forms of governance (Lemos & Agrawal, 2006) and the concepts of IWRM and adaptive governance (Chaffin, Gosnell, & Cosens, 2014). While some of these concepts were not specific to water, they all hold an important place in water management and governance. These important research efforts form the foundation for future research in this era of uncertainty and complexity. Indeed, many of the distinguishing features of these forms of water management and governance form a critical basis for, and important elements of, water resilience.

Resilience research has a substantial history as well. From its roots in ecology grew bodies of literature that branched and diverged in terms of focus, from engineering perspectives to social-ecological and community perspectives of the concept (see Folke, 2006; Davidson et al., 2016). Water management and governance scholars and practitioners were influenced by the concept of resilience and considering, for example, the importance of learning by doing in adaptive management (Walters & Holling, 1990) and a dual focus on collaboration and learning in adaptive co-management (Armitage, Marschke & Plummer, 2008). Recently, the term 'water resilience' has entered the lexicon of water researchers, practitioners, and policy makers. While definitions vary among researchers (Rodina, 2019), the focus in this book is on management and governance dimensions of water systems and their ability to persist when appropriate, to adapt when needed and to transform when the current system is untenable, to function in a way that supports ecosystem and human wellbeing. The authors of this volume have made substantive contributions to the development of our understanding of water management and governance from a water resilience lens, drawing on empirical cases and pushing conceptual boundaries.

Important to charting a course for water resilience research is to know where we are - to be reflexive - before setting out where we want to go. Accordingly, this concluding chapter is structured in two parts. The first, called 'Reflections', synthesizes the main messages from the contributions to this volume. The second, called 'Charting a Course', identifies key focal areas to consider for future water resilience research. What has become clear in writing this concluding chapter - and is not surprising - is the highly interconnected nature of the messages and focal areas that emerged from the act of synthesizing the preceding chapters. Readers are advised that cross-references are used moderately, and that the distinctions between points are somewhat artificial, which seems fitting when writing about a concept that embraces complexity.

2 Reflections

Water resilience is a continuously negotiated construct. This negotiation is similar to the manner in which resilience is defined (e.g., Alexander, 2013; Davidson et al., 2016) and is playing out in the scholarly literature (Rodina, 2019) and beyond. For example, Falkenmark, Wang-Erlandsson & Rockström (2019) and Rockström et al. (2014) have focused on water as a source of resilience and have used "water resilience" to address the essential role of water resources for sustainable development, global sustainability, and social-ecological resilience at a planetary level. Water resilience in this sense can be defined as the role of water in safeguarding and sustaining a particular desired state of a social-ecological system (Falkenmark et al., 2019). Water resilience has been proposed by Eriksson, Gordon, and Kuylenstierna (2014) as an objective to increase the resilience of society, with a particular aim to reduce hydro-climatic hazards and secure water availability of sufficient quantity and quality. The definition used by the editors of this volume draws on Eriksson et al.'s (2014) definition and work on social-ecological resilience more broadly: "the capacity to adapt or transform in the face of change in social-ecological systems, particularly unexpected change, in ways that continue to support human wellbeing" (Folke, Biggs, Norström, Reyers, & Rockström, 2016, online) with a specific focus on water systems.

In the same way as there is a lack of consensus on the meaning of water resilience in academia, the ways in which resilience is being used in the water policy contexts is also diverse. Resilience, and more specifically water resilience, has also gained attraction outside of scholarship and has been increasingly incorporated into water policy language across regions and sectors. There are a wide range of ways in which resilience is approached, making reference to critical infrastructure security (Government of Canada, 2009; The White House, 2013; Cabinet Office, 2011), institutional resilience (Stefano et al., 2010), adaptation technologies for climate change-induced hazards in the water sector (United Nations Environment Programme [UNEP], 2017), and finally more holistic approaches (Food and Agriculture Organization [FAO] & World Bank, 2018; The Rockefeller Foundation, 2015; World Water Assessment Programmed [WWAP], 2012). These references to water resilience represent a range of interpretations of the term. Different understandings of water resilience (e.g., as a singular focus on bouncing back from a specific disturbance vs. systems-thinking perspectives [e.g., Baird et al., 2016]) have important consequences for decision-making for water resources.

Authors in this volume mirror these tensions in the broader literature, policy and practice. We see slightly different interpretations of water resilience from authors, both in terms of definitions and how it is approached. In the case of Johannessen and Wamsler's chapter (12), they describe it in terms of three interacting types:

social-ecological, hazard and socio-economic. They identify benefits in using all three lenses when focusing on how knowledge is built, shared and used in group settings (i.e., social learning). Mirumachi, White and Kingsford describe a 'negotiated resilience' which emphasizes a process rather than a goal and iterative consideration by diverse stakeholders is the focus. Baird, Quinlan, Plummer, Moore and Krievins (Chap. 7) draw on the work of Folke et al. (2016) and define water resilience as encompassing of three concepts: persistence, adaptation and transformation. Their chapter develops a better understanding of the relationships among these concepts.

Water resilience is also differently used in this volume. Blythe et al. use water resilience in two ways in their chapter: first, from the perspective of the need for transformation when the current system is untenable. Second, from the recognition that we need to build the resilience of a transformation via institutionalization once it has taken place. This dual lens on resilience is indicative of the concept's broad nature and associated critiques.

So, is 'water resilience' a useful term if its definition and use varies, even among scholars working with it? We believe so! As Folke (2016: online) states:

> …respect for pluralism (e.g., Norgaard 1989), epistemological agility (the capacity to work productively across knowledge domains; McWilliam 2009), and an open mind capable of moving out of and dynamically modifying one's preanalytic vision (e.g., Costanza 2001) are assets with the potential to augment collective understanding of complex social-ecological challenges. Attempts to integrate diverse perspectives or incorporate all dimensions into one unitary approach runs the risk of undermining the intellectual wealth and dialogues necessary to meet the challenges of the globally intertwined Anthropocene (e.g., Bousquet et al., 2015; Arora-Jonsson, 2016).

It is clear that how the term water resilience is used will continue to vary depending on the scholar, the policy-maker, the practitioner. And, the concept and its diversity of interpretations may certainly continue to spur discussion and debate (e.g., Blythe, Daigle, & Baird, 2019; White & O'Hare, 2014). However, despite the range of perspectives on water resilience, the underlying interest and focus of the works contained in this volume show harmony despite these challenges: the underlying principles guiding the chapters, their focus, and their messages are consistent. This is an encouraging and hopeful finding for the future of water resilience research, and specifically the management and governance dimensions therein.

We are operating within an existing legacy of water management and governance. In many places and case studies described in the preceding chapters, this legacy is one of government-led command-and-control, of historical focus on engineering solutions to water problems, and of decision-making silos. However, in this era of the Anthropocene, many of these same places are shifting from government to governance, with efforts to develop policies and legislation that engage a greater diversity of actors, govern in a more interconnected way, and at different scales (i.e., watershed / catchment / basin scales) than previously considered. These efforts are consistent with principles that underly social-ecological resilience (Biggs et al., 2012) but also face multiple challenges associated with the legacies of the past.

Several chapters in this volume highlight some of these governance and management shifts and the legacy challenges associated with them. In the context of the EU Flood Directive, Kochskämper and Newig (Chap. 2) describe challenges from an existing legacy of technical, defense-based focus on flooding at the State level despite the Directive and its procedural requirements for multi-stakeholder participation in flood plan development. These challenges of incorporating broader participation in decision-making are echoed by Mirumachi, White and Kingsford (Chap. 10), who discuss the challenges of longstanding stakeholder interests in integrating new river basin policies into existing approaches in the Mekong River Basin, and the path dependency that results from these longstanding interests. Existing legacies can be extremely sticky, and Enqvist and Ziervogel (Chap. 9) illustrate this well in their examination of Cape Town, South Africa, where historical patterns of management and stakeholder interests create barriers to policy change, even in the case of extreme drought.

The notion of 'layering' new approaches onto existing water management and governance approaches, or integrating new approaches into old (i.e., institutional bricolage), was a common theme throughout several chapters. Roberts, Milman and Blomqvist (Chap. 3) focused on the nascent *Sustainable Groundwater Management Act* (SGMA) in California, which compels local level agencies to work together and coordinate methodologies, metrics and goals. Enactment of the SGMA is encountering challenges in terms of layering on a new management scheme (i.e., adaptive management) onto existing projects and plans – that these are sometimes incompatible making a shift extremely difficult and potentially infeasible.

Trimble et al. (Chap. 6) identify that transitions to a polycentric, participatory governance approach for water in their South American case studies are hampered by the existing legacy of command-and-control and associated issues of power being held by a central government, and challenges associated with the need for inter-institutional cooperation and power sharing among levels.

Time emerges as an important and related factor here: time is needed for shifts to approaches consistent with a water resilience perspective to occur given the legacy of past water management and governance approaches and resistance / barriers due to path dependency. A major shift in the form of a transformative policy may require an equally large shift 'on the ground' and this requires sufficient resources and time to facilitate the shift (Roberts et al., Chap. 3). However, the authors also note that there can be pressure to make potentially transformative changes happen quickly and that this creates challenges in terms of time lags from bureaucracy and decision-making related to new governance approaches.

Time is also a critical factor in *when* shifts take place. Several chapters reference the potential for change when windows of opportunity present themselves. A concrete example of this was provided by Enqvist and Ziervogel (Chap. 9), where a severe drought lead to greater engagement of the community in urban water governance. Blythe et al. (Chap. 11) through several case studies of ocean governance, show that transformational change can happen quickly when windows of opportunity present themselves, but that there is an important preparation phase that is needed in order to take advantage of these opportunities, and a resilience-building phase thereafter to institutionalize the transformation. Blythe et al. emphasize that these phases occur within the context of existing and historical policy and thus transformations may experience constraints and barriers. They use the example of the Food and Agriculture Organization's (FAO) small-scale fisheries guidelines, and the hesitance to accept them due to existing, overlapping policies and a lack of sufficient consultation in the FAO's guideline development. These insights from Blythe et al. mirror those from other chapter authors described above in relation to broadening participation. Mirumachi et al. caution in Chap. 10 that windows of opportunity may not always pave the way for change, and that resistance to change can be strong due to path dependency.

There are also potential benefits to not 'starting from scratch': In some cases, existing arrangements can serve to enable water resilience. For example, Roberts et al. indicate that local agencies charged with working together to create a basin-wide groundwater management plan were developed for other purposes in the past and thus come to this challenge with prior experience. However, this 'institutional bricolage' (i.e., "how mechanisms for resource management and collective action are borrowed or constructed from existing institutions, styles of thinking and sanctioned social relationships" [Cleaver, 2002, p. 16]) can inhibit the novelty of these agencies and the possibility of barriers due to path dependence remains.

Water governance that includes multiple actors and a combination of top-down and bottom-up approaches is often preferable. Water issues are inherently complex. Water does not adhere to administrative boundaries, and disturbances and feedbacks in water systems occur, and interact, across scales (e.g., spatial, temporal, jurisdictional) and levels within those scales (see Cash et al. [2006] for a full description of scales and levels). Accordingly, a single actor (e.g., a national government) is not well-situated to govern water alone (Pahl-Wostl, Jeffrey, Isendahl, & Brugnach, 2011). Here, our focus is on the jurisdictional scale and a range of levels. Many perspectives across levels and a suite of available tools are needed for water governance now and in the future. Many of the authors in this volume recognize a role for both governments and non-governmental actors in water governance. They focus on examples of existing and potential combinations of approaches and highlight the rationales, respective roles of actors and challenges of such approaches.

Enqvist and Ziervogel (Chap. 9) recommend combining top-down and bottom-up approaches in urban settings, arguing that they can promote multilevel governance and address the challenges therein and situate their work within cities in the global South. They emphasize that bottom-up initiatives are important and provide an example of engagement in envisioning processes for institutional change, but that these types of initiatives cannot implement higher level change on their own. They suggest that organizations that cross levels and create the potential for equal footing for all actors (in their case study, a lake group in Bengaluru, India), can support the integration of top-down and bottom-up water governance. A complementary perspective is provided by Trimble et al. (Chap. 6), who highlight the importance of higher-level policies and legislation to enable regional / watershed-based water management in three countries in South America. The reforms at the national level to water policy has enabled polycentric governance, recognition of social-ecological systems, broad participation and planning processes at multiple levels in Argentina, Brazil, and Uruguay. However, the authors emphasize that context matters and identify critical factors that moderate success to include the level of authority of the national government, nature of the policies and legislation, and how long the country has been engaged in participatory water management. Important connections are evident here to the above insights regarding the importance of the legacy of water governance and time as a factor.

Cosens and Gunderson (Chap. 8) elaborate on the attributes necessary for a multi-actor, adaptive approach to water governance, including governments creating the capacity for governance to occur by providing the structure, authority and assistance to work across actors and jurisdictions in a participatory way, the process and structure that assures legitimacy and accountability, and the ability to institutionalize these types of solutions through law. Many of these attributes are confirmed by Roberts et al. as well in their discussion of groundwater governance in California in Chap. 3. However, Cosens and Gunderson focus on adaptive, incremental change to existing institutional arrangements in watersheds across North America, whereas Roberts et al. (Chap. 3) focus on designing an entirely new institution for governance (albeit within existing institutional structures and policies). Further, Roberts et al. indicate in their chapter that groundwater management in California is still in its infancy and the extent to which the institution addresses concerns of including diverse perspectives - like legitimacy, equity, accountability (similar to concerns identified by Cosens and Gunderson) - is uncertain and already showing to be variable, especially given that the SGMA does not provide specific requirements about how actor engagement occurs or extent of that engagement. Kochskämper and Newig (Chap. 2) identify challenges of this type of 'procedural' policy instrument in the EU with the Water Framework Directive and Flood Directive, where flexibility is offered in how it is implemented. However, Kochskämper and Newig found that the participatory process in developing watershed-wide plans and measures fell short of expectations in the cases they studied. These two chapters highlight a tension between top-down and bottom-up approaches in terms of not only challenges of multiple scales and coordination but also in the procedural aspects and governance legacy (i.e., not wanting to change too much) that ultimately result in sub-optimal outcomes. Clearly, the structure and authority that governments can provide for water governance, and the interactions between governmental and non-governmental actors, requires a high degree of nuance that recognizes the specific context within which it is situated and principles of good governance.

Finally, Marshall and Lobry de Bruyn (Chap. 4) identify serious challenges associated with bringing local level governance into a centralized system in the Murray Darling Basin in Australia. Institutional resistance and power dynamics played key roles in resisting a hybrid governance approach. However, they also note that innovation and change is possible and that, in recent years, bridging organizations have, at the local level, engaged in water governance with increasing impact at the broader basin scale over the past 25 years. This 'bubbling up' of local initiatives, while not a wholesale transformation at the basin scale, may create the potential for such a transformation.

3 Charting a Course

Here, attention turns to promising avenues for future research – areas where the contributing authors and editors have identified a need for further study on specific topics within the management and governance dimensions of water resilience. Three key focal areas for research have emerged from this volume: continued focus on how to manage and govern water at multiple scales; the issue of power and power dynamics in water management and governance; and, further emphasis on social learning and its potential contributions to both understanding water management and governance processes and enhancing them.

Water governance levels and interactions. It is clear from one of the main messages emerging from synthesis of the contributed chapters that the jurisdictional levels at which governance occurs - and in many cases interactions across multiple levels - are important areas of focus for water resilience research going forward. Defining appropriate levels of governance, the ways in which governance is organized within and across levels, which actors are involved, to what extent, and their relative roles and responsibilities are complex questions.

Johannessen and Wamsler (Chap. 12) advocate for watershed / catchment / river basin level governance, emphasizing that water and risk management to support social-ecological system resilience needs to occur at the appropriate level. They remind us that this is not a new call to address fit; scholars have been identifying this as an issue for over 20 years. However, connecting back to the notion that we work within a legacy of management and governance, Johannessen and Wamsler describe the difficulty of implementing basin-scale management in a system where municipalities are tasked with assessing flood risk making coordination difficult. Further, the authors connect the issue of the scale of governance with increasing risk to those who are vulnerable and marginalized, as they are likely to be disproportionately affected by disturbances and require governance efforts at the community level.

Enqvist and Ziervogel (Chap. 9) focus on urban settings but emphasize that they are necessarily embedded within higher regional to international levels with multilevel dependencies for direct and indirect water uses. They state that these multilevel dependencies become more critical to focus on in the face of rapid climate change and an emerging global water crisis. They indicate that integration between community and whole-city levels governance provides a better understanding of the plurality of water issues through the promotion of participation and learning. Strengthening this type of governance, however, requires further research according to Enqvist and Ziervogel. They call for research focused on: how multilevel partnerships are facilitated in the face of power dynamics and low trust; assessing impacts of bottom-up approaches in multilevel governance; and, they call for greater researcher engagement in governance processes to facilitate collaboration but also warn that due consideration of their positionality is required.

Similarly, Reilly et al. (Chap. 5) discuss the relationship between local level management (in their case, at the level of the individual farmer) and interactions with higher level governance / policies along with the ecological implications of local management decisions at the watershed level. They provide the example of nutrient reduction policy occurring at national or subnational level, but that actions are implemented at an individual level. There are thresholds at the watershed level that must be met for individual actions to be effective. Resilience perspectives can be better integrated into studies of agricultural pollution and social-ecological systems to support cross-level considerations. Further, Reilly et al. highlight another critical scale – that of time. Time was raised as a key message previously in this chapter, in relation to the challenges of shifting policies and approaches to water governance, or even transforming governance systems. Reilly et al. bring a different, more ecologically focused perspective to the issue. Though management practices are implemented in a watershed, the ecosystem's recovery can be slow, and the effects of management changes may not be realized for a long time. This relates to the slow variables and feedbacks principle of resilience (Biggs et al., 2012; Baird et al., Chap. 7) and the importance of long-term thinking and understanding the social-ecological system when developing policy. The interactions between slow variables from an ecosystem perspective and slow variables in a social system described above warrant further research.

Finally, Trimble et al. (Chap. 6) emphasize that *how* multiple levels of governing bodies work together (or not) matters, using Argentina's complex water policy landscape as an example, and that further research is needed to better understand interactions across levels. The policies, legislation and authority over water resources at each level can impact whether or not polycentric governance can work. Further, and consistent with a resilience mindset, considering disturbances from outside the system is critical.

Power is a critical consideration in water resilience. Critiques have been directed at resilience scholars for a lack of attention to power in the conceptual development of social-ecological resilience (e.g., Cote & Nightingale, 2012; Fabinyi, Evans, & Foale, 2014). Scholars are increasingly acknowledging and focusing on the important role of power in resilience of social-ecological systems (see Stone-Jovicich, 2015; Hahn & Nykvist, 2017, e.g., Folke et al., 2019), and in water governance and management specifically (e.g., Ratner et al., 2013; Brisbois & de Loë, 2016). In line with this emerging shift in the literature, we also see references by many authors in this volume to power dynamics and allied issues (equity, legitimacy, accountability [e.g., Cosens and Gunderson in Chap. 8]). It is encouraging to see substantive acknowledge of power in water resilience scholarship. A potential next step is to devote a volume to power, as it is a multi-faceted and complex concept that permeates many of the governance dimensions of water resilience and is increasingly being taken up by scholars.

Several authors in this volume identify power being a factor in their chapters. The relationship between multilevel governance and power became evident in some of these chapters. Roberts et al. (Chap. 3) approach power in an indirect way in considering the respective roles and responsibilities of local entities that engage in basin-level planning and that of local governments and the state in enforcing pre-existing laws and the SGMA. The relative power of each of these is implicit in their discussion of the potential challenges of the SGMA in achieving water resilience. Trimble et al. (Chap. 6) identify participatory (and polycentric) water management as an approach that has strengthened society's capacity to both question existing policies and demand improvements to both quantity and quality in Brazil. Blythe et al. (Chap. 11) emphasize the exclusion of local voices in contemporary ocean governance approaches as a rationale for the need for transformation. Similarly, Mirumachi et al. (Chap. 10) connect with power through their examination of stakeholder involvement and varying capacities to influence decision-making. They identify power imbalances and voices of only a few stakeholders (the state, irrigators) as a key reason why the Murray-Darling River basin remained set in a damaging, outdated paradigm ('hydraulic mission') despite major water allocation and environmental flow challenges.

Chapters that discussed community-focused / bottom-up water governance and management approaches also touched on power. Johannessen and Wamsler (Chap. 12) advocate for a community-based approach to water governance (through local leadership and capacity building) to empower vulnerable populations, using the lens of socioeconomic resilience. They make mention of the need to understand 'power struggles' and identify joint actions between communities and policy makers as one way to address power asymmetries, or else reproduce them. Baird et al. (Chap. 7) identify factors in relation to adaptive and transformative capacities that are reflective of distribution of power among diverse actors and the example of the Cowichan Watershed in British Columbia, Canada, provides some evidence of efforts to share power. However, Enqvist and Ziervogel (Chap. 9) call for caution in promoting bottom-up water management and identify recommendations from Smith (2008) in this regard: genuine commitment; understanding communities; having realistic expectations and providing adequate facilitation. They caution that the language used and aggregation of people into 'communities' (for example) can mask the heterogeneity of urban residents and places and cognisance and consideration of heterogeneity, contested values and the dynamics of systems are critical.

Finally, Blythe et al. indicate that much of the existing empirical work on transformations is not focused on 'navigating turbulent transitions' and shifts in power. Mirumachi et al. provide an example of how a lack of consideration of power issues (inclusivity and transparency) can be an important barrier to transformation and being able to utilize windows of opportunity in the Colorado River Drought Contingency Plan development process. Further, Blythe et al. emphasize that as we move forward with water resilience research related to transformations, we should ask the important questions: 'transformation by whom, for whom?' (Blythe et al., 2018).

Continued study of social learning in the context of water resilience is needed. Social learning has been a focus for scholars in multiple fields related to water resilience (e.g., natural resource management, adaptive co-management, environmental / water governance) (see for example de Kraker, 2017; Cundill &

Rodela 2012; Lebel, Grothmann, & Siebenhüner 2010; Mostert et al., 2007; Muro & Jeffrey, 2008; Pahl-Wostl, 2009; Reed et al., 2010). Likewise, social learning is often identified in social-ecological resilience literature as a concept of key importance (e.g., Biggs et al., 2012; Folke et al., 2016). Despite this sustained attention to social learning, it remains a complex concept that still has much room for development in the context of resilience, and water resilience specifically. Three chapters address social learning explicitly, and the focus of this section is on the insights and research needs identified therein.

Johannesssen and Wamsler (Chap. 12) approach social learning from a risk management perspective. They note that the focus on social learning so far is insufficient in an urban context and contribute to filling this gap by identifying key factors that support social learning. Specifically, they use Sweden as a case study, identifying the need to transform risk management to increase focus on prevention and mitigation to reduce the need to focus on crisis management. They contend that this requires single-, double- and triple-loop learning, bringing currently disparate entities together and transforming governance and management systems to address appropriate scales, priorities and knowledge integration. Further, the authors connect social learning to addressing power imbalances, and to create more equitable decision-making for risk management and awareness-, knowledge- and capacity-building in marginalized and vulnerable populations.

Reilly et al. (Chap. 5) identify the potential, but so far limited use, of social learning to enhance the management of agricultural systems, citing benefits of creating shared understandings of the social-ecological system and its dynamics that may otherwise limit collective action – which they argue is needed as the current system focuses on technical measures. Thus, Reilly et al. emphasize the applied benefits of a greater focus on social learning and its particular importance in the context of bottom-up approaches to agro-ecosystem governance.

Finally, Mirumachi et al. (Chap. 10) state that the "goals, means and implications of [social] learning" are not clearly defined when put into practice for resilience. The authors go on to state that studying social learning can provide insights into power relationships, contested values and trade-offs in decision-making. Thus, there are clear interconnections to other key messages and focal areas for future research.

In addition to the chapters that addressed social learning explicitly, it is worth noting that many authors addressed related topics such as participatory approaches and multi-stakeholder processes. These approaches and processes create the conditions for social learning to occur and further emphasize Mirumachi et al.'s call for more focus on social learning in resilience-focused research. Greater and more explicit attention to social learning in water resilience research is needed to better understand its potential for all three processes of water resilience as outlined in Baird et al. (Chap. 7): persistence, adaptation, and system transformation.

4 Conclusion: Water Resilience for Our Shared Future

Water resilience is a multi-faceted and dynamic concept. It is not a panacea, but its complexity is advantageous – it is nimble and flexible and responds to the dynamics of complex systems and changing needs. Water resilience is a promising lens with which to approach water management and governance in this era of the Anthropocene.

The key messages and focal areas for future research identified in this final chapter are intertwined. Mirumachi et al. provide an excellent example of this in their concluding paragraph in their Mekong River Basin case: "…engineering knowledge maintains superiority over ecological or social science; furthermore, it works to delegitimise and render local knowledge less useful. This elitist decision-making securely puts into place path dependency on the hydraulic mission, focusing on water abstraction" (p.10). In this short phrase, the authors reference path dependency and existing institutions, power relationships and the influence of these factors on what knowledge is available in learning processes. Governance and management legacies, time, multi- and cross-scale governance, hybrid governance, power, and social learning are interrelated and, in some cases, difficult to distinguish. The nature of water resilience – as an overarching concept that encompasses this wide but interrelated range of topics – requires diverse perspectives and expertise. This volume attempted to bring a range of these perspectives together, and in that process recognized the degree to which these topics are intertwined. Our rationale for this approach was that we have much to learn from those applying a water resilience lens to water management and governance approaches being practiced, and also from those who are focused on pushing the conceptual boundaries of water resilience – both what is, and what could be.

We are experiencing unprecedented times of change in modern history. But, we are equipped with an equally unprecedented, and growing, understanding of social-ecological systems, water resources and the management and governance approaches that hold potential in light of this era where change and surprise are constants. This volume represented an opportunity to both take stock of what we know about the management and governance dimensions of water resilience, and to chart a course for the future of water resilience research as we continue to navigate towards a sustainable future for water, the planet and humanity.

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