Received: 5 September 2023 | Revised: 21 April 2024 | Accepted: 25 April 2024

DOI: 10.1002/wat2.1734

PERSPECTIVE

WIREs WATER WILEY

Setting a pluralist agenda for water governance: Why power and scale matter

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Funding information
Norges Forskningsråd grant Riverine Rights: Exploring the Currents and Consequences of Legal Innovations on the Rights of Rivers, Grant/Award Number: 301916; U.S. National Science Foundation Award, Grant/Award Number: 2231605; the U.S. Geological Survey's Water Resources, and Ecosystems Mission Areas;

Abstract

Global water systems are facing unprecedented pressures, including climate change-driven drought and escalating flood risk, environmental contamination, and over allocation. Water management and governance typically lack integration across spatial scales, including relationships between surface and ground water systems. They also routinely ignore connectivity across temporal scales, including the need for intergenerational water planning. As a global and interdisciplinary group of scientists, we seek to highlight how power and scale dynamics influence and determine water outcomes. We argue that attending to complex water systems challenges requires understanding the function and influence of power at different temporal and spatial scales. Building this understanding is key to designing multi-scalar, reflexive, and

NOAA grant "Western Water Assessment: Building resilience to compound hazards in the Intermountain West", Grant/Award Number: NA21OAR4310309

Edited by: Naho Mirumachi, Associate Editor, Wendy Jepson, Senior Editor, and Jan Seibert, Editor-in-Chief

pluralistic policy solutions that avoid ineffective or unintended outcomes. We use a co-learning process to reveal important lessons for the challenge of interdisciplinary research and set a pluralist agenda for understanding power and scale in future water governance.

This article is categorized under:

Human Water > Water Governance

Human Water > Water as Imagined and Represented

Human Water > Methods

KEYWORDS

interdisciplinary water research, power, scale, water governance, water management

1 | INTRODUCTION

The health of the world's water systems, and the people who rely on them, are under increasing pressure. This is evident in the devastating, climate change-fueled floods and droughts experienced globally (Fischer et al., 2021), increasingly over-extracted surface and groundwater resources (Gleeson et al., 2012), and environmentally degraded aquatic ecosystems (Vörösmarty et al., 2010; Wheater & Gober, 2015); all occurring in the context of inequitable access to water and its benefits across society (Savelli et al., 2023). Water-related crises not only reflect a changing hydroclimate, but also failures in water governance (Di Baldassarre et al., 2019) resulting from power dynamics that play out in complex ways over space and time.

Historical examples of water system challenges caused by legacy power dynamics are numerous. A leading example is mid-20th century dam development in western North America as an outgrowth of the doctrine of "manifest destiny." Dam construction was based on a paradigm that prioritized development and agriculture, locking in water allocation rules inconsistent with current water resource availability (Walsh, 2012), and failing to adequately account for Indigenous water rights and authority. These contemporary challenges are inherited from historical decisions made by a powerful few, but have significant, long-term impacts for water and people. They lie at the heart of the ongoing Colorado River crisis (Kuhn & Fleck, 2019).

Responses to water governance challenges continue to be dominated by technical and siloed thinking and management approaches (Martin-Ortega, 2023). In this perspective, we argue that we cannot attend to complex water systems challenges without understanding the function and influence of power at different temporal and spatial scales, and that doing so necessitates an interdisciplinary and pluralist water research agenda. We are an interdisciplinary team of scientists, who came together at the 2022 *AGU Chapman Meeting* "Solving Water Availability Challenges Through an Interdisciplinary Framework" with the shared aim of highlighting the role of power and scale dynamics in global water governance. With our combination of European, European settler, Asian and Indigenous heritage, we work across all continents in a broad range of fields: anthropology, ecology, hydrology, geography, law, Indigenous studies, geology, risk management, psychology, and systems science. Our team brings diverse cultural perspectives on complex water system challenges from the Global North and South, spanning career stages from early career to emeriti, and spatial scales from large river basins to small rural catchments and aquifers.

The perspective is structured as follows. In Section 2 we explain why a pluralist research agenda is needed to understand power and scale for future water governance. In Section 3 we draw on post-structuralist theory to understand how uneven power relations influence water governance. In Sections 4 and 5 we add a scale lens to our power analysis, examining the way that power dynamics play out across time and space to influence water outcomes with examples from our diverse study sites. We conclude our perspective by arguing that by engaging diverse and multiple worldviews emphasizing relationality between people and water we can better understand the evolving dynamics of water governance challenges across temporal and spatial scales.

2 | SETTING A PLURALIST WATER RESEARCH AGENDA

The complexity of water system challenges complicates the process of finding solutions, and means that no single knowledge source or approach will guarantee transformation to water governance or its outcomes (Pahl-Wostl et al., 2013). Despite important progress towards interdisciplinary scholarship in socio-hydrology (Ross & Chang, 2020; Sivapalan et al., 2012;; Wesselink et al., 2017), socio-ecological systems (Grant et al., 2002; Wang & Grant, 2021), hydrosocial theory (Boelens, 2014; Linton & Budds, 2014), and normative pluralism (Curran, 2019; Tamanaha, 2008), research on coupled human and water systems is still poorly integrated across disciplines and cultures.

These silos of understanding are reflected in modern water governance, which is typically fragmented across spatial domains and routinely ignores connectivity across surface and groundwater (National Academies of Sciences, Engineering, and Medicine, 2018); relationships between water quality, quantity, and broader ecosystem health; and connections across terrestrial and marine spaces (Cumming, 2013).

Recent calls to action by water researchers in diverse fields emphasize the need for new water paradigms and science agendas that conceive of water as more than H_2O (Leonard et al., 2023; Poelina et al., 2021; Sproat, 2011), and recognize the deep interdependencies of social and physical systems (Martin-Ortega, 2023) with deliberate attention to issues of power and scale (Pahl-Wostl, 2015). This paper responds to those calls.

While knowledge of our study sites and disciplines formed the basis of our exchanges as an interdisciplinary research group, our place-specific, disciplinary, and cultural frames also complicated our efforts to articulate the role of power and scale in water governance and management. Yet we persisted with this research collaboration, because of our shared commitment to water governance based on pluralistic and interdisciplinary understanding of water and its positionality. That is, that water lives within complex, integrated systems (Alcamo et al., 2008), including the web of interrelationships with surrounding natural (including human) processes, and social and economic institutions (Boelens et al., 2016; Douglas et al., 2019; Ross & Chang, 2020; Wesselink et al., 2017). We accepted that we as individual researchers did not need to have identical disciplinary and cultural positionalities with respect to water in order to

BOX 1 Key definitions

Term	Definition
Governance[a]	The social function that regulates development and management of water resources and provisions of water services at different levels of society and guides the resource towards a desirable state and away from an undesirable state. A water governance system is the interconnected ensemble of political, social, economic, and administrative elements that performs the function of water governance. These elements embrace institutions as well as actors and their interactions.
Management[a]	The activities of analyzing and monitoring water resources, as well as developing and implementing measures to keep the state of a water resource within desirable bounds.
Policy making	The processes that establish the scope and content of new water policies.
Decision making	The processes of making administrative decisions as part of water governance or management.
Power	The ability of actors to assert their interests, including through influencing water decision-making outcomes, even in the face of resistance from other actors.
Scale[b]	The spatial, temporal, thematic and organizational dimensions of water system processes.
Pluralism	Approaches to management, governance and research that respect and enable diverse water cultures, knowledge, and worldview.
Information	We rely on the DIKW understanding of information as part of a hierarchy of data, information, knowledge, and wisdom used in water management and governance.

[a] Pahl-Wostl, 2015, p. 26.
[b] Wang et al., 2023, p. 2.

advance our collective research agenda, but adopted the mutually defined key concepts in Box 1 to frame our engagement.

To understand relationships between human, natural, and social systems, we rely on hydrosocial scholarship that emphasizes dynamic relationships between peoples and water (Alcamo et al., 2008; Linton, 2014). This approach enables us to pay close attention to the social circumstances of water distribution to consider how water, social structures, power relations, and technologies are internally related. It encourages us to increase the representation of historically excluded actors and knowledges, specifically Indigenous worldviews, for which water's value extends far beyond quantifiable H_2O or its market value (Fisher et al., 2022; Leonard et al., 2023; Sproat, 2011; Poelina et al., 2021). We view water as part of a "hydrocosmological" cycle (Boelens, 2014) that allows for diverse water cultures, knowledges, and worldviews to present new potential paths toward transformative water governance.

To ensure sustainable and equitable water futures in an increasingly uncertain world, we must properly identify and diagnose water governance failures. Through explaining our case studies to each other in a co-learning process, we identified site-specific problems and cross-cutting themes, and found that complex power dynamics typically accompanied governance failures. These power dynamics have a space–time dimensionality: spatial and temporal scale mismatches of varied physical, social, and ecological processes often caused or contributed to water governance failures. Both scale and power have long been themes in water governance research. Yet the relationship between scale mismatches and historical and evolving power dynamics are difficult to comprehend – they are often obscured, assumed, or unquestioned. Thus, a crucial first step towards transformative water governance is enhancing the visibility of both power dynamics and scale mismatches.

This article begins from the position that in order to improve water governance, we need to understand how power dynamics affect decision making at different spatial and temporal scales. Developing such an understanding can be aided by interdisciplinary co-learning, enriched by systems thinking that accounts for water pluralism (Howitt & Suchet-Pearson, 2006), through purposefully examining cases through diverse social and cultural water perspectives and paradigms. We propose a novel approach to water research involving:

1. interdisciplinary research methodologies to design and implement transformative governance solutions that are attentive to power and scale; and
2. research exchanges that pay attention to overlooked water paradigms, histories, and contexts, including those rooted in Indigenous Knowledge Systems (Raman, 2023), and that seek to shift power structures in new, scale-sensitive ways.

3 | POWER FLOWS THROUGH COMPLEX WATER SYSTEMS

Because policy and decision making occurs against a backdrop of complex power dynamics, rendering these dynamics visible can aid the critical evaluation and revision of water governance arrangements. We share the perspective that social impacts of quantifiable variables such as reservoir water level, river flow, fish population, or flooding frequency exist in the context of power-laden human activities, shaping flows and withdrawals.

There is a large and varied multidisciplinary body of research on the influence of uneven power relations in water governance (Liévanos, 2017; Svarstad et al., 2018). For this perspective we are influenced by "poststructuralist" understandings of "modes of power," encompassing the interrelationship of power, knowledge and institutions (Dehm, 2021), operating at multiple (Nagendra & Ostrom, 2012) tiered levels of actors across scales (governments, communities, organizations and individuals) (Dakyaga et al., 2023; Marks & Hooghe, 2004). In the water context, we understand power as being dispersed throughout complex, multilevel, water governance systems. This understanding of power is appropriate here because it reflects our understanding of the complex, hierarchical nature of water governance relationships. It is also useful for us in seeking to contribute new perspectives to the historically dominant, rigid approaches to water management developed by the natural sciences and engineering or other hegemonic thinking about the political economy of water such as neoliberalism (Boelens, 2009). That is, because it rejects essentialism and instead highlights the multiple perspectives, positionalities, and knowledges (Leonard et al., 2023) of diverse water actors engaged in a complex web of water relations (Woodward et al., 2009).

Our analysis focuses on the ways in which certain actors use their social position and status to secure social, economic, or political gains (Bourdieu, 1986, p. 352) and influence water governance including via physical and financial infrastructure (Wittfogel, 1957). Favorable outcomes for powerful actors often come at the expense of other users, and

disadvantaged actors can often be distinguished by race, culture, class, sex and gender (Larson, 2020; Strang, 2016). For example, the original negotiations between the United States and Canada for the 1961 Columbia River Treaty ignored the rights and interests of Indigenous Peoples within the basin in favor of flood control and electricity generation (McKinney et al., 2016). In general, the interests and agency of water itself have typically been ignored in Western tradition (Hikuroa et al., 2018).

Power manifests through individual actors and their ability to dominate transactions as well as structural power, which influences institutions, knowledge production, and societal norms (Brause, 2021; Wolf, 1999). Theories of power are used to explain both *resource extractivism*, the exploitation of natural resources, and *fortress conservation* (Brockington, 2002), the prioritization of Western conservation values over Indigenous or local livelihoods (O'Donnell et al., 2020). These manifestations shape water resource governance, and, given the dependencies of human-water relationships, the everyday lives of people (Pahl-Wostl et al., 2013).

Pahl-Wostl offers a framework for recognizing power through three distinct yet overlapping "governance modes" (Figure 1) (Pahl-Wostl, 2015). These modes differ as to the degree of formality of institutions, the role of state versus non-state actors, and the nature of relations between actors. *Hierarchies* embrace formalized power (e.g., legal rights), where those at the top of the hierarchy can use their dominance either for the benefit of the collective, or their own (i.e., corruption, rent seeking). In *networks*, an actor's position determines power; a central actor may control information flows or can influence other actors or even other networks. Networks emerge largely from self-organization, though actors can use their power to steer the network in a certain direction. Finally, in *markets*, power is expressed through economic resources. In idealized markets an "invisible hand" would drive an optimal collective outcome by balancing the demand and supply of a scarce resource. However, powerful actors may interfere with the market, for example, by controlling access to resources or prices, or by accumulating resources to maximize individual benefit (Douglas et al., 2019).

States and regional governments are routinely considered to be the primary actors in complex water systems, but governance (and power to influence decision-making) is carried out through all three modes (Dehm, 2021, p. 43): States/nations (bureaucratic hierarchy), markets, and civil society (networks). While hierarchies can reinforce power structures favoring the interests of the elite (e.g., via political capture), they are also influenced in complex ways from the bottom up. These include legal and extra-legal systems of water distribution, cooperation, and governance

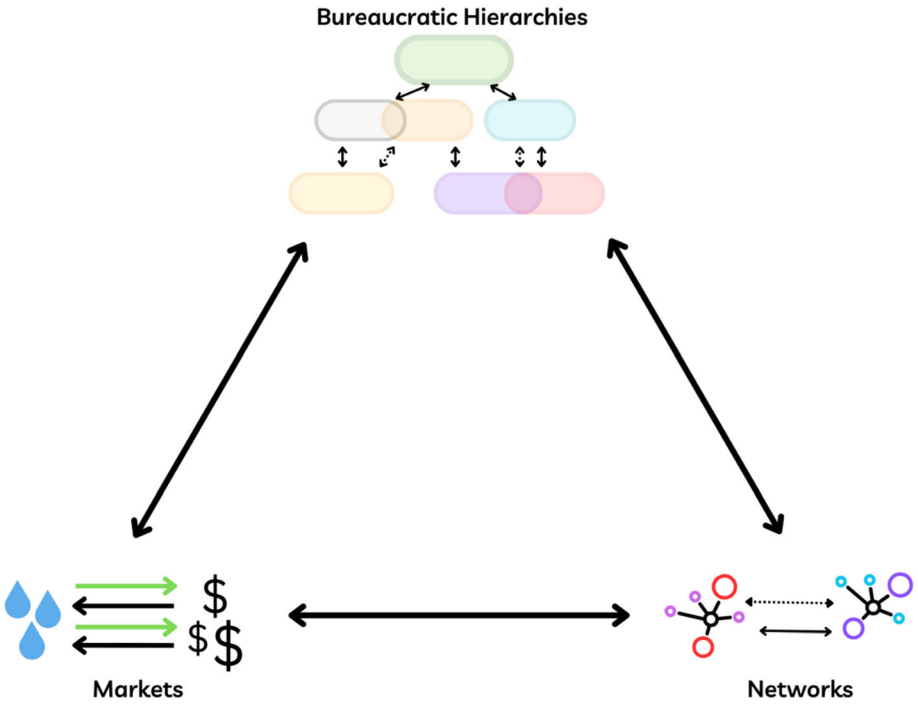

FIGURE 1 Water governance occurs within and across interactions of bureaucratic hierarchies (decision-makers in states/nations/municipalities), networks (connected actors with lateral interactions), and markets (economic forces and trade) (adapted from Pahl-Wostl, 2015). Interactions may be formal (solid lines) or informal (dashed lines).

(including place-based, Indigenous-led governance systems) (Ostrom, 1998), which may exist without formal recognition and operate well without formal jurisdiction recognized by governments.

Powerful actors may use combinations of governance modes to exercise power that marginalizes others, producing increasingly unaccountable and extra-governmental water regimes in which the control of water is placed in "fewer and fewer hands" (Strang, 2016, p. 293). This concentration of power tends to reinforce itself over time and space; those with historical access to water can maintain and expand it, even in the face of declining water availability (Perez-Silva & Castillo, 2023).

Synergies in governance modes may also lead to more balanced distribution of power in polycentric governance systems (Pahl-Wostl, 2019). However, there is little empirical analysis on the performance of different governance arrangements and the role of combinations of governance modes and the influence of different power constellations.

4 | COMPLEX WATER SYSTEM POWER DYNAMICS RIPPLE ACROSS TIME AND SPACE

The relationship between power and scale is difficult to define. Powerful actors can influence outcomes in ways that are visible, hidden, or invisible (Gaventa, 2006), producing significant social, ecological, and hydrological consequences over time and space (Figure 2). While a water management decision might appropriately resolve a conflict based on an understanding of direct cause-and-effect for a key water process at a given spatial unit (e.g., effects of surface water allocation on streamflow along a specific reach), its rippling effects may include indirect, distal impacts observed across different scales of space at time (e.g., long-term decline of a downstream estuary or coastal ecosystem).

While the influence of a powerful actor might be observable in any one case, identifying complex power dynamics is challenging because power is dispersed across multiple, distributed, and tiered levels of actors and governance modes (Marks & Hooghe, 2004; Nagendra & Ostrom, 2012), and power dynamics operate differently at different scales (Brause, 2021). Social norms also create invisible or internalized power by establishing acceptable ways to interact with water systems (e.g., for human benefit while neglecting ecosystem health).

The imposition of new governance modes through colonization and settlement exemplifies the impact of power dynamics over temporal scales. Agricultural and municipal water users across the Colorado River Basin, for example, have been able to accumulate water rights, while prior Indigenous water rights have still not been properly accounted

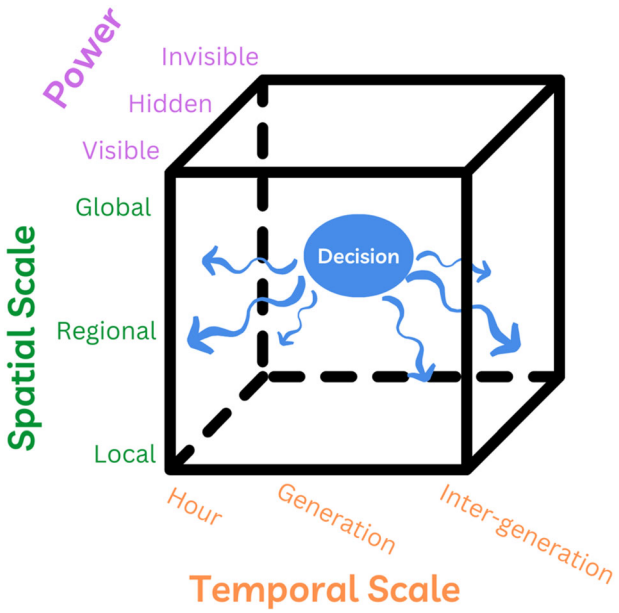

FIGURE 2 The power cube (adapted from Gaventa, 2006). Water decisions are made for a single spatial unit, at a single point in time, influenced by powerful actors in a visible, hidden, or invisible manner, with implications that ripple out across spatial and temporal scales.

for. The water corresponding to "paper" rights that Indigenous groups hold (as a consequence of political settlements or court determinations that recognize their priority water rights) may remain in-stream and be diverted for other uses (e.g., drinking water, environmental flows, agriculture) (Arizona v Navajo Nation, 2023). Part of the challenge in utilizing these paper rights is the lack of access to physical infrastructure to enable water utilization; as water distribution infrastructure was historically designed for municipal and agricultural users. This is an example of "path dependency" or "lock in" in settler colonial contexts (Parsons et al., 2019), where power is concentrated in the hands of settlers at the expense of Indigenous peoples, over time. Another example can be found In the Lower Rio Grande (USA), where physical and social water infrastructure was designed early in the 20th century to support irrigated agriculture, but today urban, industry, and service users increasingly demand water (Walsh, 2012).

Groundwater systems provide a further example of the operation of power dynamics propagating across spatiotemporal scales, as certain actors may use their economic power to pump from declining aquifers and disadvantage other dependent groundwater users. In both the Trinity (Texas, USA) and Columbia (Delaware, USA) aquifers, actors who can afford to install wells have access to groundwater, and if they draw less than 25,000 and 50,000 gallons per day respectively (limits set based on water availability and use at a particular point in time), they remain exempt from regulation (Office of the Registrar of Regulations, 1987; Texas Water Code, 1971). In the Trinity aquifer, population expansion in groundwater dependent areas is increasing the demand for groundwater and increasing the number of permitted domestic wells (Paup & Jackson, 2022). Despite regulations regarding well spacing in some areas, continued pumping causes overlaps in cones of depression and leads to well interference, potentially leading to large and unexpected reductions in water levels at the community level (Bracken, 2010). Such reductions in local water levels lead to the construction of deeper wells, which may exacerbate existing problems for other nearby groundwater users. In the Columbia aquifer, municipalities have greater pumping resources and are protected from saltwater intrusion by being farther inland compared to coastal farmers. The farmers are at risk of both aquifer drawdown and saltwater intrusion from the nearby Delaware Bay, hindering irrigation.

While water governance routinely operates within spatially defined administrative and political boundaries, hydrologic processes and system footprints rarely fall neatly within the spatial boundaries of municipalities, provinces, and states working within short-term political and administrative planning cycles. As such, there is a risk that complex, place-based socio-hydraulic realities can be lost in large-scale water systems governance. An example is Canada's Saskatchewan River Basin, which spans the provinces of Alberta, Saskatchewan, and Manitoba. The river's headwaters initiate in the Canadian Rocky Mountains and the river flows through Canada's agricultural prairie heartland before dispersing in the Saskatchewan Delta. Dam construction during the development-intensive 1960s obstructed summer flood flows that naturally refreshed delta wetlands, with severe impacts on downstream ecosystems and the livelihoods of First Nations (Evans, 2018). Agricultural activities in the middle reaches of the basin have degraded river water quality through nutrient pollution producing algal blooms that shut down Regina's drinking water supply (Buffalo Pound Water Administration Board, 2015). As illustrated by Gober and Wheater (2014), phosphorus concentrations downstream of Alberta's intensive agriculture exceeded Alberta's historical guideline by up to an order of magnitude. Alberta's response was to remove the guideline (Alberta Environment, 2018), replacing it with a non-specific narrative, and the overarching decision-making body, the Prairie Provinces Water Board, has opted to restrict phosphorus levels to not exceeding current concentrations (PPWB, 2021). This illustrates the global challenge of balancing the needs of agricultural production with environmental protection (National Academy of Engineering, 2008).

At a local scale, the loss of 70% of prairie wetlands (Cortus et al., 2011) that normally retain water and nutrients (Brunet & Westbrook, 2012) has contributed to recent flooding in the Saskatchewan River Basin, due mainly to agricultural practices (Cortus et al., 2011). Despite flooding of downstream communities and First Nations territories, little action has historically been taken. However, the increasing severity of flooding has driven the implementation of legislation to require licensing of current and historical drainage (Saskatchewan Water Security Agency, 2017), a challenging task given the complex environments and historical legacies. In this case, environmental change is becoming a key driver for changing water governance.

Large river basins that cross legally defined spatial boundaries, like the Saskatchewan River Basin, illustrate the difficulties of effective governance and potential for conflict across complex physical and social processes (Ross & Chang, 2020; Rusca & Di Baldassarre, 2019; Wesselink et al., 2017). They also elucidate why multi-level and multi-scalar governance perspectives are needed to better understand the impact of power dynamics across spatial and temporal scales, in order to support water system transformation (Pahl-Wostl, 2015).

5 | INFLUENCING WATER VALUES AND PRIORITIES ACROSS SCALES

Institutional theorists have long argued that the processes of setting values and priorities in complex water systems governance has a determinative effect on water outcomes (Talbot-Jones & Bennett, 2022). However, water governance priority-setting—and the knowledge relied on by decision makers to set priorities—can be infused with unequal relationships of power (Boelens, 2009). Powerful actors can strategically influence the setting of water governance priorities to serve their own interests at scales convenient for them and may be able to control what counts as knowledge by others (Parsons et al., 2019). The myriad ways in which water governance is influenced by the interests of powerful actors may not be visible to other affected actors or the broader public.

Our cases indicate that although local actors working at smaller scales, and often in decentralized and distributed ways, may have holistic, nuanced, and intergenerational knowledge about localized water conditions (Leonard et al., 2023; Poelina et al., 2021; Sproat, 2011), they may have less power to determine formal water governance priorities. They may face difficulties in elevating their priorities to the top bureaucratic hierarchies to influence decision making at larger jurisdictional and spatial scales. For example, in the Whanganui catchment (New Zealand, known as Aotearoa in the Māori language and often referred to as such locally in community, government, and policy contexts (Smith and Holster, 2023)), despite the rights and authority of local Māori (Iwi) being recognized in a catchment-level governance arrangement arising out of a negotiated Treaty settlement, their ability to influence water outcomes according to their specific river values and priorities can be undermined by national-level resource management laws administered by regional government at a much larger spatial scale (O'Donnell & Macpherson, 2023). In the case of Roshi watershed in Nepal, small farmers residing in the upstream region encounter difficulties due to the power and resources held by downstream elites, who can possess capital and political influence. (Kovács et al., 2019). However, the upstream communities in Roshi have begun to bypass local, regional, and national decision-makers and have approached international development organizations to advocate for their first right to water use, seeking to influence and advocate for their needs and priorities (Devkota & Neupane, 2019).

Decision and policy makers setting water priorities at large spatial scales may not fully understand the implications of a particular water management decision for diverse actors at local scales and vice versa (Wang et al., 2023), evident for example in the Saskatchewan example discussed above. However, effective cross-scale feedback through relationships between affecting actors (decision makers) and affected actors (interest groups) can shift power dynamics towards local actors, or at least better reflect their priorities (Figure 3).

By initiating and strengthening relationships and power-sharing with previously missing or marginalized actors, cross-scale feedback processes can reduce the risk of biased decision making. Strategically balancing feedback across

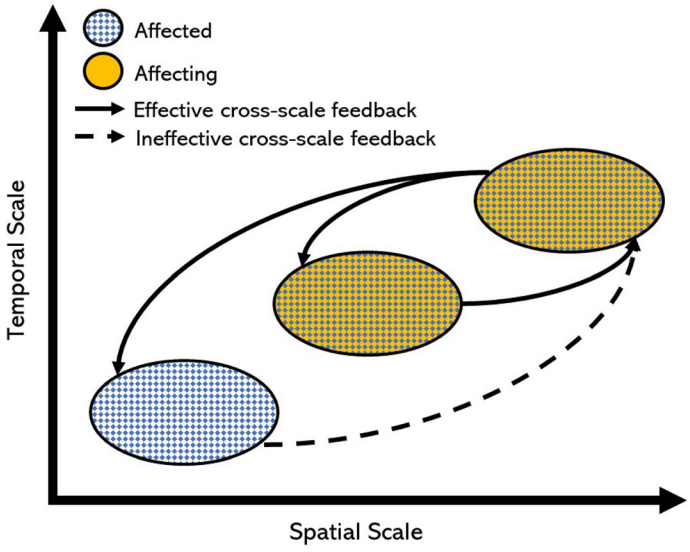

FIGURE 3 Water governance decisions affect multiple actors that may be operating at different spatial and temporal scales. Interactions between actors may be one-way, with "affecting" actors impacting "affected" actors in direct ways (solid lines) without strong feedback in return (dashed lines). Actors may also effectively influence each other, such that they are both affecting and affected, in some cases at different scales (e.g., short-term impacts versus long-term, regional effects and local feedback).

affecting decision makers and multiple affected actors includes multi-directional communication and exchanges, voting, and inclusion in decision making, not just through a seat at the table but a *voice* at the table.

Decision makers in formal water governance processes also have a particular time-scale lens when making water management decisions, often driven by short-term political, administrative, or planning cycles. Temporal scale mismatches, such as conflicts arising from historical legal and physical infrastructure that have "locked in" certain patterns of water use (e.g., irrigation), may be more difficult to address via cross-scale feedback, given the inaccessibility of past or future actors. However, relational water paradigms (drawing on water pluralism) suggest potential for a more holistic and inter-generational approach to water systems governance, in ways that transcend limiting spatial and temporal boundaries.

6 | TOWARDS A PLURALIST UNDERSTANDING OF POWER AND SCALE

We found that powerful actors frequently benefited at the expense of other water users, but who held power varied across cases. For example, while the agricultural sector was a powerful actor in Saskatchewan, farmers may be disadvantaged in the Columbia aquifer and Roshi watershed. The rights and knowledge of Indigenous Nations are often marginalized. In the Columbia River Basin, Indigenous rights were ignored in the original Columbia River Treaty (McKinney et al., 2016; United States Department of State, 2023), and historical power asymmetries continue in the Colorado River Basin. The Supreme Court of the United States recently held in a narrow majority (5/4) that although the Navajo held reserved water rights under an 1868 Treaty and the United States owed trust-like duties to them, the United States was not under an obligation to take affirmative steps to secure water for the Tribe (Arizona v Navajo Nation, 2023).

Yet, social and environmental crises can provide "shocks" to the system that generate transformations in water governance. On O'ahu in the Hawaiian Islands, the local government has historically been unable to enforce environmental regulation on lands used by the U.S. Navy, which has stored millions of gallons of fuel over the island's sole source aquifer for decades despite long-standing concerns over potential for contamination. While a 2014 spill at the Red Hill Bulk Fuel Storage Facility set the stage for increased oversight of the facility by the U.S. Environmental Protection Agency (U.S. EPA) and Hawai'i State Department of Health (https://www.epa.gov/red-hill/2015-administrative-order-consent) it was not until a 2021 fuel release that contaminated the Navy's own drinking water supply (Jedra, 2021), and sickened hundreds (Miko et al., 2023; Troeschel et al., 2022), that ensuing public and political pressure shifted power dynamics (Cocke, 2022; Singh, 2024). The Hawai'i Department of Health and U.S. EPA are now exercising regulatory oversight to ensure safe defueling and closure of the Red Hill Bulk Fuel Storage Facility and protection of the area's drinking water (United States Environmental Protection Agency, 2022).

The concentration of power in the hands of a few can lead to the marginalization of water's own needs (Haraway, 2016)—the most important actor in water governance (Guerrero, 2018)—rendering water invisible in Western governance traditions that treat it only as a resource. Reductions in absolute water availability in water systems such as the Colorado River Basin, which no longer makes its natural journey to the sea, emphasize the benefit of pivoting from purely extractive approaches focused on human benefit and consumption to broader ecosystem needs.

Existing mainstream water paradigms may differ from relational Indigenous ontologies that emphasize water bodies such as rivers and lakes, and their interconnected territories (Womble et al., 2018), as living entities to which related peoples owe duties of care (Hikuroa et al., 2018). The Indigenous Māori Iwi of the Whanganui catchment (New Zealand) secured state recognition of their power and authority with respect to the river through a negotiated Treaty settlement that centered the power of the river as an actor and rebalanced governance authority towards the Iwi (Macpherson, 2023). The governance model recognizes the status of the Whanganui River in their intergenerational worldview as a living and indivisible whole from the mountains to the sea, and effects legal recognition of the river (which they relate to as an honored ancestor) as a "legal person." The Indigenous-led governance model for the river territory is based on their relational law, which transcends traditional legal and scientific spatial and temporal conceptions of river systems and provides space for holistic, intergenerational, and inclusive water management, policymaking, and decision-making (Cribb et al., 2022).

The Whanganui case illustrates how, instead of focusing on the "services" a river provides to human communities, centering water system health (together with related communities) can shift power dynamics. This may bring us closer to an arrangement where human actors engage governance modes to work in the interest of the water system in ways

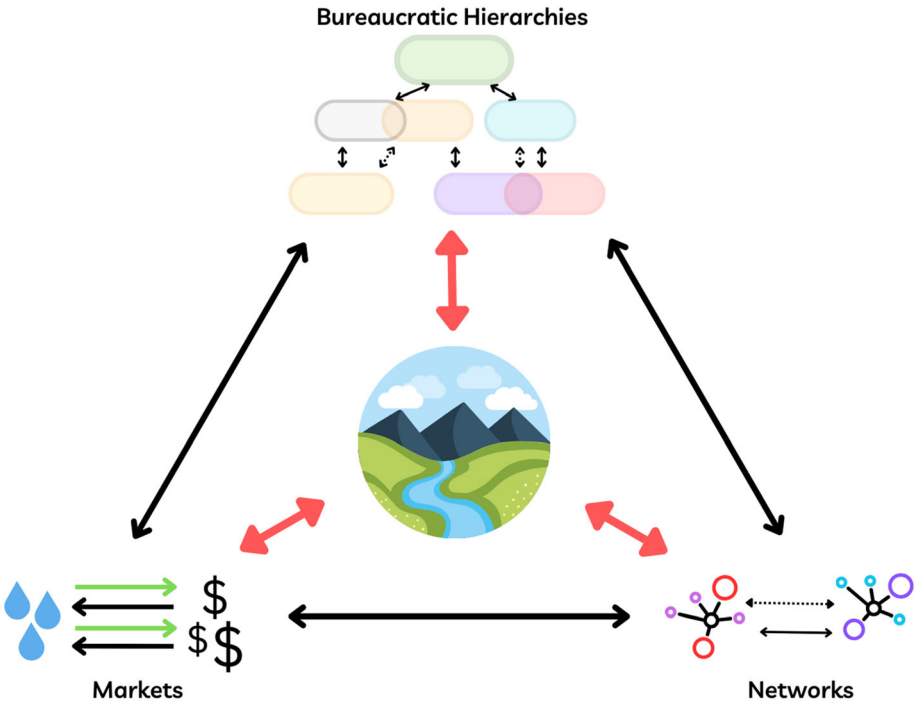

FIGURE 4 Putting the water system at the center of governance. This framework centers the physical and social-ecological realities of the water system (river, catchment, aquifer, irrigation system, etc.) within the governance setting to highlight that not only do these modes influence each other but interact via the water itself.

that are more responsive to natural processes and indicators (Figure 4). Indeed, if we were to allow agency for water itself then structures of power would need to shift. Such an approach is inherently multi-scalar and inclusive of plural, diverse processes and actors that operate on intergenerational time frames. A focus on living water system health also forces consideration of not just physical metrics but understanding coupled socio-ecological relationships and processes at the appropriate (and varied) spatial and temporal scales at which they occur.

7 | CONCLUSION

The water governance problems in the examples discussed in this perspective are symptomatic of patterns of distress in water systems around the globe. These patterns can be exacerbated by historically entrenched power structures, which may fail to account for the varied assemblage of diverse actors with wide-ranging water needs and relationships across generations.

Applying Western traditions of understanding water as a purely physical substance is often inadequate to govern complex water systems and the myriad conflicting needs and power dynamics within them (Fisher et al., 2022; Poelina et al., 2021). We argue here that water pluralism, engaging diverse and multiple worldviews emphasizing interconnections between people and water, can help us to understand the evolving dynamics of water governance challenges across temporal and spatial scales (Guerrero, 2018; Linton & Pahl-Wostl, 2023).

How can this water pluralism be actualized and operationalized? Progress towards transformative water governance solutions for the future will require thoughtful integration of infrastructure, water quality, water availability, and social, cultural, and environmental concerns. Yet persistent silos within both water research and water governance challenge the development of decision-making processes that skillfully incorporate interrelationships of decisions across scales, sectors, and disciplines. Transformative water governance depends on advances in interdisciplinary work that draws on the social, ecological, and physical sciences and provides a rigorous foundation for addressing unacknowledged power dynamics as well as biophysical realities within complex water systems.

How can such interdisciplinary be achieved? This perspective is the product of months of discussions, disagreement, compromise, and breakthrough of a research team from fields that do not frequently work together. During this process, we learned how our fields diverge and converge and observed how our respective research efforts are limited by the processes and scales on which we focus and our varied understandings of power. The productive tension and dialogues forced us to articulate our assumptions and conceptualizations about complex water system governance. We navigated through differences to reach agreement by applying the same relational approach that can be applied in water governance to our *own* research relationship: that is, we focused on opportunities to connect, reciprocate, and adapt to each other over time in a co-learning process that produced quite a different research environment and output than any of us had worked with before.

Others can build on our learning experience: to draw on plural disciplinary and cultural perspectives to build understandings of power-laden water relationships across multiple spatial and temporal scales. Our collective experience tells us that embracing a co-learning process can provide fertile ground beyond interdisciplinary water research and support adaptive co-management and collaborative governance for waters of the future.

AUTHOR CONTRIBUTIONS

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ACKNOWLEDGMENTS

The authors would like to thank Dr Karen Grant and Rachael Mortiaux for their helpful research assistance. Open access publishing facilitated by University of Canterbury, as part of the Wiley - University of Canterbury agreement via the Council of Australian University Librarians.

FUNDING INFORMATION

Elizabeth Macpherson received funding from Norges Forskningsråd grant Riverine Rights: Exploring the Currents and Consequences of Legal Innovations on the Rights of Rivers [grant number 301916], NOAA grant "Western Water Assessment: Building resilience to compound hazards in the Intermountain West" [grant number NA21OAR4310309]. Support for the American Geophysical Union Chapman on Solving Water Availability Challenges through an Interdisciplinary Framework was provided by the U.S. National Science Foundation Award ID 2231605 and the U.S. Geological Survey's Water Resources, and Ecosystems Mission Areas.

CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest for this article.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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How to cite this article: Macpherson, E., Cuppari, R. I., Kagawa-Viviani, A., Brause, H., Brewer, W. A., Grant, W. E., Herman-Mercer, N., Livneh, B., Neupane, K. R., Petach, T., Peters, C. N., Wang, H.-H., Pahl-Wostl, C., & Wheater, H. (2024). Setting a pluralist agenda for water governance: Why power and scale matter. *WIREs Water*, *11*(5), e1734. https://doi.org/10.1002/wat2.1734