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Understanding rivers and their social relations: A critical step to advance environmental water management

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Abstract

River flows connect people, places, and other forms of life, inspiring and sustaining diverse cultural beliefs, values, and ways of life. The concept of environmental flows provides a framework for improving understanding of relationships between river flows and people, and for supporting those that are mutually beneficial. Nevertheless, most approaches to determining environmental flows remain grounded in the biophysical sciences. The newly revised Brisbane Declaration and Global Action Agenda on Environmental Flows (2018) represents a new phase in environmental flow science and an opportunity to better consider the co-constitution of river flows, ecosystems, and society, and to more explicitly incorporate these relationships into river management. We synthesize understanding of relationships between people and rivers as conceived under the renewed definition of environmental flows. We present case studies from Honduras, India, Canada, New Zealand, and Australia that illustrate multidisciplinary, collaborative efforts where recognizing and meeting diverse flow needs of human populations was central to establishing environmental flow recommendations. We also review a small body of literature to highlight examples of the diversity and interdependencies of human-flow relationships—such as the linkages between river flow and human well-being, spiritual needs, cultural identity, and sense of place—that are typically overlooked when environmental flows are assessed and negotiated. Finally, we call for scientists and water managers to recognize the diversity of ways of knowing, relating to, and utilizing rivers, and to place this recognition at the center of future environmental flow assessments.

This article is categorized under:

Water and Life > Conservation, Management, and Awareness

Human Water > Water Governance

Human Water > Water as Imagined and Represented

Keywords

environmental flows; environmental water allocations; freshwater; rivers; social-ecological systems

1 | INTRODUCTION

Freshwater is arguably the most critical substance for life on Earth: it is essential for ecosystem health and underpins the economies and lifeways of human populations around the world (UN Environment, 2017; WWAP, 2018). For generations, water resource management as conceived and practiced in more industrialized regions of the world has construed freshwater as a natural, asocial substance that can be objectively known and—in efforts to maximize its potential as a resource—controlled and regulated for human welfare. Thus “knowing, accounting for and representing water apart from its social context” is part of a particular modern hydrological knowledge paradigm that, by the end of the twentieth century, had come to dominate the myriad ways to know and relate to freshwater (Linton, 2014, p. 111; Wantzen et al., 2016; Magdaleno, 2018).

For numerous reasons, the modern conception of water as a substance abstracted from social, cultural, and religious context has come under heightened scrutiny. Consequently, there has been greater interest in addressing how water is not just natural, but also historical, political, and cultural. This interest has generated attention to approaches other than eco-hydrological methods to know and understand water and has led to increased recognition of the complexity of the relations between water, society, and ecosystem processes. This is, for instance, manifest in recent scholarship on socio-hydrology (Sivapalan, Savenije, & Blöschl, 2012) and the hydro-social cycle (Bakker, 2012; Boelens, 2014; Linton & Budds, 2014), both bodies of work in which natural and social researchers collaborate because they acknowledge the need to understand water flows and systems as both social and natural (Wesselink, Kooy, & Warner, 2017). Although the viewpoints emerging from socio-hydrology and the hydro-social cycle are founded on different knowledge paradigms, they are rooted in the core idea that water systems—like rivers—and society coevolve and emerge through continued engagement over space and time (Wantzen et al., 2016). Ethnographic studies of customary hydraulic systems and their communal water management institutions have also contributed to such an understanding. These include the subak irrigation system (cooperatives) of Bali (Lansing, 2006) and the self-sufficient acequia systems that have persisted for several hundred years in the southwestern United States (Cox, 2014). The increased scholarly acknowledgement of the mutual constitution of society and water has also been translated into policies and international frameworks that seek to address complex, interdependent societal challenges, for example, the Sustainable Development Goals (SDGs). A specific goal for water—SDG6: *Ensure availability and sustainable management of water and sanitation for all*—along with other SDGs focused on peace, justice, climate, conservation, and well-being, seek to explicitly link water and social relations (Wiegleb & Bruns, 2018).

Those interested in environmental flows also increasingly recognize the importance and complexity of relationships between humans and freshwater bodies. According to the renewed Brisbane Declaration of 2018, the term environmental flows refers to: *the quantity, timing, and quality of freshwater flows and levels necessary to sustain aquatic ecosystems which, in turn, support human cultures, economies, sustainable livelihoods, and well-being* (Arthington et al., 2018; Box 1). Environmental flow assessment—also sometimes referred to as environmental water allocation or environmental water management—is a critical step in establishing a societally-acceptable threshold between water available for off-channel allocations and water to be retained within or returned to a waterbody to sustain ecosystems. The science of environmental flows embraces the full range of aquatic ecosystems, however the focus of this paper is on rivers and their social relations.

Despite the inclusion of a hydro-social perspective in the new definition and advances in several assessment frameworks (Poff, Tharme, & Arthington, 2017), the science and practice of environmental flows has so far remained faithful to distinctly modern methodologic traditions. These traditions have their origins in the biophysical sciences and are mostly premised on a separation between nature and society. With some exceptions (Acreman et al., 2014; King, Tharme, & Villiers, 2000; Poff et al., 2010), the overwhelming majority of approaches used for determining environmental flows remain based predominantly on (a) hydrology; (b) physical habitat simulation for fish or other aquatic biota; or (c) flow-ecology relationships where people are excluded from important ecological relations or concepts, like aquatic food webs (Tharme, 2003). Few studies have considered the role of river flow in the livelihoods and well-being of local communities and highlighted vital social and economic dependencies. Consequently, the embedded, reciprocal, and constitutive relationships that many human populations have with water and rivers continue to be poorly understood.

We argue that a challenge for environmental flows research and implementation is to understand natural systems *in relation* to the social world, in line with what those who seek to advance hydro-social thinking are trying to do (Wesselink et al., 2017), and to appreciate rivers and their flow regimes as social-ecological systems (McGinnis & Ostrom, 2014). We posit that rivers are socially constituted in at least three ways. First, historical, social, and political processes and contexts shape ways of knowing (e.g., conceptualizing and making abstractions about water and eco-hydrological processes) and acting on the environment, or in this case, rivers and waterways. As we will describe, the growing commitment to environmental flows and the expansion of methodological approaches grew from a shared political concern from environmentalists and scientists about the future of rivers and river-dependent ecosystems and societies. They were particularly concerned about those waterways directly affected by the modernist mode of water management, one that transformed rivers through regulatory infrastructures or other river alteration measures. Second, implementation of the prescriptions promoted by environmental flows scientists and advocates requires effective frameworks, technologies and institutions (norms, rules, laws), as well as widespread political-social support and alignment with the aspirations of those people responsible for and living with rivers subject to alteration. Third, the implementation of environmental flows will have social and political consequences that result from decisions to redistribute water or share it differently, by “taking away” water from some and allocating it to others or allowing it to remain in the environment. Similar to environmental flows, the importance and influence of societal values, priorities, and perceptions of nature also are increasingly recognized as inherent to river restoration (Lave, 2016; Smith, Clifford, & Mant, 2014).

This paper is the first to synthesize knowledge of relationships between people and rivers as conceived under the renewed definition of environmental flows (see Box 1). We trace the historical underpinnings of environmental flows and explore how social norms and values have influenced scientific understandings of rivers, a neglected aspect of the historiography of river science. We then review a specific but small body of literature that describes multidisciplinary efforts in which satisfying diverse flow needs for human livelihoods or well-being has been central to setting environmental flow recommendations. Several of these efforts were undertaken with the realization that implementing environmental flows requires active support of stakeholders, as well as their knowledge, spiritual beliefs, and the symbolic meanings they attribute to rivers. We conclude with a discussion of the diversity of flow-human relationships that typically remain overlooked when environmental flows are assessed and negotiated (Table 1), and a call for greater recognition of these relationships.

The ideas presented here emerged from discussions among ~25 people at a week-long workshop on social and eco-hydrological linkages to environmental flows, convened in June

2017 at the Socio-Ecological Synthesis Center (SESYNC) in Annapolis, Maryland, USA. Workshop participants intentionally represented diverse backgrounds (e.g., government, non-government, Indigenous) and nationalities, and collectively brought together decades of experience in theory, research methods, assessment, negotiation, and implementation of environmental flows, and/or knowledge of the varied connections human societies maintain with rivers.

2 | HOW HAS ENVIRONMENTAL FLOW SCIENCE HISTORICALLY CONCEIVED OF RIVER-HUMAN INTERACTIONS?

There is some evidence that state water management practices considered some aspects of societies' relations with rivers and the social significance of flowing water, even before environmental flows took shape as a scientific field and river conservation practice in the late 20th century. Yet, this consideration was often partial, with river relationships maintained by certain marginalized groups, such as Indigenous peoples in setter societies, afforded little regard or protection by modernist (and in many cases, colonial) approaches to water management (see Emanuel, 2019; Estes, 2017; Robison, Cosens, Jacskon, Leonard, & McCool, 2018). In 1915, in a move to recognize the aesthetic value of a river, Oregon (USA) prohibited the diversion of water from certain streams that sustained the spectacular falls of the Columbia River Gorge (Lamb & Doerksen, 1987). A 1917 agreement from India shows that the British colonial government recognized the importance of flows for religious purposes on the Ganges River and duly amended plans for water infrastructure following interjections from local rulers (General Administration Department, No. 10, April 28, 1917). In the 1960s–1970s, scientists in southern Africa investigated the intricate relationships between the livelihoods of the Thonga people and floodplain dynamics along the Pongola River (Heeg & Breen, 1982; Tinley, 1964). Their studies informed recommendations for managed flow releases from an upstream impoundment to meet fishery and other tribal needs downstream, although that advice was not incorporated into operating rules at the time. Such frontrunners to the concept of environmental flows are not well recognized in the international scientific literature.

In the documented histories of river conservation (e.g., Poff & Matthews, 2013), it was the era of extensive dam building that promulgated the concept and practice of environmental flows. In the mid-20th century, and particularly in the United States, development of water supplies by the agencies of the state using large-scale infrastructure was the prevailing response to the problems of "modern" water management (Linton, 2014). The first generalized set of environmental flow recommendations is commonly attributed to Donald Tennant, a biologist who, while working for the U.S. Fish and Wildlife Service during the 1950s–1960s, made hundreds of observations about flow-altered and unaltered rivers in Montana, Wyoming, and Nebraska. Based on these observations, Tennant devised the Montana Method for calculating minimum, moderate, and excellent flow levels to protect aquatic resources downstream from dams based on varying percentages of average annual or seasonal flow (Tennant, 1976). By 1969, Montana had become the first U.S. state to provide for the legal acquisition of a water right for in-stream uses, a move that also allowed its fish and game department to acquire such rights (Lamb & Doerksen, 1987). Other U.S. states followed suit, stimulating the need for scientifically legitimate methods of assessing flows. Although the Montana Method is often described as hydrology-based method, a lesser-known fact is that the underpinning research also included studies of “fishing and floating” and “esthetics and natural beauty” as outcomes linked to river flows, and documented water velocities suitable for white-water boating.

The 1970s–1980s witnessed a shift from equating environmental flows with hydrology-based minimums to greater recognition of relationships between flow and hydraulic conditions linked to physical habitat for aquatic organisms and to recreational uses of water (Stalnaker, Lamb, Henriksen, Bovee, & Bartholew, 1995; Tharme, 2003). Additionally, in the United States, a growing multiple-use ethic of water led to the consideration of water budgets for different uses, such as instream fisheries, and understanding that these budgets vary across the year. During this period, the Instream Flow Incremental Methodology (IFIM), developed by the U.S. Fish and Wildlife Service, U.S. Geological Survey, and other partners, created an analytical framework to evaluate various alternatives for use of instream flows within a hydrologic time series. IFIM is often confounded with the Physical Habitat Simulation System (PHABSIM), a tool that links open channel hydraulics with aquatic biota and calculates habitat available for different fish life stages at varying flow levels (Bovee & Milhous, 1978). However, PHABSIM forms only one component of IFIM. The overall structure of IFIM heralded recognition of the value of an interdisciplinary approach to instream uses, including not only water management and hydrology, but also political science and law. It offered a platform to recognize all users of water in decision-making about environmental flows, including recreational and Indigenous tribal uses (Stalnaker et al., 1995). The more integrated framing of IFIM is not as frequently used, nor as well known as the quantitative aspects of PHABSIM, but in reality, it represented an early awareness of diverse human connections to the flow characteristics of rivers.

Appreciation for recreational uses and their linkages to river flow gained additional strength in the 1970s–1980s. Brown, Taylor, and Shelby (1991) reviewed ~25 river-specific studies of recreational quality, economic value, and esthetics, and their interactions with other needs for river flows. They distinguished between direct effects of river flows on recreational attributes of rivers—such as quality of flows for boating, fishing, and scenic beauty—and indirect or longer-term effects related more to the form and function of river channels and riparian habitats. These studies consistently identified a range of responses to putative minimum, optimum, and maximum flow conditions, thereby highlighting the importance of considering variation in perceptions among recreationalists (Brown et al., 1991). Around the same time (1980s–1990s), in response to adjudication of water rights in the western U.S., the U.S. Forest Service developed an approach to identify channel maintenance flows to reflect the original intention of national forest protection defined in the Organic Administration Act of 1897 (Schmidt & Potyondy, 2004). Flows that would maintain stream channels over time could also ensure the delivery of water to downstream users.

The development and application of more comprehensive approaches to determining environmental flows—often referred to as “holistic” approaches (sensu Tharme, 2003)—represented a further development in systematically recognizing the connections between people and rivers (Poff & Matthews, 2013). From the late 1980s, as scientists grew more aware of the inherent variability in a river's hydrologic regime and the importance of this variability to multiple aspects of a river's ecology (Poff et al., 1997; Richter, Baumgartner, Wigington, & Braun, 1997), they were increasingly preoccupied with the conservation and management challenges posed by widespread river alteration, particularly by hydropower dams (Cushman, 1985; Dynesius & Nilsson, 1994; Ligon, Dietrich, & Trush, 1995). This era (mid-1990s to early 2000s) saw the development and application of two new methodologies that incorporated societal goals for the future ecological condition of a river when setting flow objectives. The first of these was the Building Block Methodology (BBM) developed in South Africa (King et al., 2000). A second methodology, known as Downstream Response to Imposed Flow Transformations (DRIFT), explicitly considered the "sociological" consequences of flow-related biophysical changes, giving them equal weight to other impacts encompassed by a "biophysical module" (King & Brown, 2006). Using DRIFT, flow alterations affecting fisheries (Arthington, Rall, Kennard, & Pusey, 2003), riparian vegetation, and water quality (King, Brown, & Sabet, 2003) were considered by teams that comprised specialists involved in the fields of ecology, livestock health, public health, anthropology, sociology, water use, and resource economics (King & Brown, 2006).

This period marked an advance in environmental flows through a broadened perspective to an ecosystem level, greater involvement from various stakeholders in establishing goals for river flow management, and recognition of socio-economic dependencies on flows and consequences of altered flows for human communities. Nevertheless, several limitations remained. Most environmental flow approaches of this time saw the natural world as separate from and external to the social world and sought to reconstruct an "original nature" against which human environmental practices such as flow alteration could be judged (Richter et al., 1997). As a consequence of this framing and because of a biocentric approach to the research task, the focus in most methodologies remained on ecologically significant variables and processes, and their linkages to flow. Social considerations were limited to descriptions of how altered flows could affect vulnerable people; measured impacts typically related to subsistence reliance on fish and other aquatic resources, rather than being used as metrics to help set environmental flow recommendations around underlying human interactions with rivers. Furthermore, most progress on approaches described as "holistic" was still limited to a small number of regions, primarily South Africa and Australia (Arthington, 2012; Poff & Matthews, 2013; Tharme, 2003).

By the turn of this century, the development and application of environmental flows had spread worldwide, with various motivating factors (Poff et al., 2017). For example, in the African nations of Kenya and Tanzania, numerous flow assessments were conducted in response to new water policy frameworks that gave second priority to ecosystems in water allocation decisions, following satisfaction of basic human needs for water (Dickens, 2011; Kabogo, Anderson, Hyera, & Kajanja, 2017; McClain, Kashaigili, & Ndomba, 2013). A proliferation of new hydropower projects precipitated environmental flow assessments in other places—such as Central and South America (Anderson et al., 2018; Anderson, Pringle, & Rojas, 2006; Esselman & Opperman, 2010), southeast Asia including China (Illaszewicz, Tharme, Smakhtin, & Dore, 2005; Wang et al. 2009; Blake et al., 2011) and Central Asia (USAID, 2017). While these approaches maintained a heavy focus on hydrology or habitat-based methodologies, they included a social assessment component in some cases (e.g., Poff et al., 2017). Here, as with the cases referred to above, these assessments relied primarily on ecological variables to understand and quantify the relationships between people, flows and desirable ecosystem properties, often with a strong focus on economic consequences for riparian communities.

From the mid-2000s to the present, globalization has increasingly transformed and unified the science and practice of environmental flows. The first Brisbane Declaration (2007) established a common definition and global action agenda to advance environmental flows science and management. It also consolidated an international community of environmental flows practitioners that included scientists, water agencies, environmental NGOs, and engineers—those who had historically been involved—with newcomers to environmental flows from the financial, government, humanitarian, and development assistance sectors (Poff & Matthews, 2013). Together, this community has expanded environmental flows science and practice far beyond its historical foundations. Today, numerous countries in Central and South America, Africa, and Asia have established legislation and advanced practical experience related to environmental flows (Anderson et al., 2011; McClain & Anderson, 2015; Poff et al., 2017; Harwood et al. 2018).

The international community also moved to synthesize and scale up scientific knowledge of ecological responses to flow alteration (Arthington, Bunn, Poff, & Naiman, 2006). The regional Ecological Limits of Hydrologic Alteration (ELOHA) framework emerged, and with it a river basin approach that articulates and quantifies testable hypotheses of ecological responses to altered flows to guide environmental flow determination (Poff et al., 2010). The ELOHA incorporates human dimensions into environmental flow setting through explicit consideration of societal preferences for flow conditions and through its commitment to adaptive management (Poff et al., 2010). Nevertheless, similar to earlier methodologies seeking to incorporate societal or human dimensions and variables, the core of ELOHA's framework focuses on flow alteration-ecological response relationships. Among ELOHA's limitations is that it has yet to consider the profound and complex interactions between people, river flows, and the governance of water, or to give critical attention to the relationships between science and society. ELOHA also privileged eco-hydrological science in the making of flow recommendations (see Finn & Jackson, 2011; Pahl-Wostl et al., 2013).

In an effort to incorporate matters of governance and strengthen the capacity for comparisons between different rivers, some researchers set out to improve the consideration ELOHA had given to the social sciences in a new framework referred to as Sustainable Management of Hydrological Alterations (SUMHA) (Pahl-Wostl et al., 2013). The revised approach sought to achieve greater engagement in environmental flows research and traction within the water management sector by attending explicitly to the needs of stakeholders and including social sciences in assessment, sectoral tradeoff analysis, and other steps (Pahl-Wostl et al., 2013). However, the framework could have benefited from deeper reflection on its foundational ontological and epistemological assumptions. As with previous methodologies, SUMHA and the underpinning ELOHA framework rely on an understanding of "nature" as external to social relations. More precisely, in these models, researchers conceive of water and ecosystems as resources that exist independently of social relations and can be objectively known and quantified by scientists. Furthermore, SUMHA adopts the framework of "ecosystem services" to bridge the social and eco-hydrological realms without questioning whether a universal approach to value articulation will assist the goal of understanding differences across the socio-ecological systems of the world's rivers. Relational values are the key to pluralistic environmental valuation (Himes & Muraca, 2018), and so the emphasis given by SUMHA to instrumental values is one of its limitations.

That SUMHA is premised on the ecosystem services framework is not surprising given that the globalization of environmental flows has been accompanied by growing and widespread recognition of the ecosystem services concept (MEA, 2005). Freshwater ecosystem services are described as the numerous benefits humans derive from rivers and other aquatic systems in terms of provisioning goods like water, food, or fiber; regulating processes like flood control; supporting services like nutrient cycling or waste assimilation; and cultural appreciation of freshwater through spiritual and recreational benefits (Bark et al., 2016).

Since the concept's ascendance, freshwater ecosystem services have often been used in environmental flow assessments to describe a one-way flow of benefits from the human uses of rivers (Forslund et al., 2009; Gilvear, Beevers, O'Keeffe, & Acreman, 2017; Gopal, 2016). Although the intention has been to raise awareness of human dependencies on rivers, in our view, the ecosystem services concept is inadequate in that it stresses nature's provision of goods and services, but neglects the embedded, reciprocal and constitutive relationships that many human populations have with water and rivers (Emanuel, 2019; Huertas & Chanchari, 2011; Jackson & Palmer, 2012; Tipa & Nelson, 2008). Rivers are not merely biophysical phenomena that constitute a component of an objectified and externalized nature that provides services to people. The relationship of the Lumbee people to the Lumbee river of North Carolina exemplifies the essential shortcoming of this economic concept. Informed by his experience as a Lumbee person and environmental scientist, Emanuel (2019) stresses the "bi-directional" or reciprocal relationship maintained by his tribe and its river. While acknowledging that the Lumbee River provides distinctive benefits, the relationship is not unidirectional:

> "Lumbee people respect and honor the river, and they spend time in and around its waters for work, recreation, and worship. In doing so, the people and the river have each infused the other with identity to the extent that both share the same name (p. 5)."

As this quote reveals, rivers and their waters mediate social relationships through belief systems, cultural identity, institutions, knowledge and technology (Figure 1). Flows connect people who relate to rivers through habitual practices and experiences that are influenced by ethics, morals and other means of socialization, and these relationships in turn shape flow regimes (Emanuel, 2019; Wantzen et al., 2016). Human societies come to know the meaning of water and rivers from within social relationships (Bakker, 2012; Krause & Strang, 2016). By emphasizing the relational character of human-river interactions, the concept and practice of environmental flows can provide a framework for improving our understanding of rivers as social-ecological systems.

To date, this kind of relational thinking has gained the most traction in contexts where Indigenous peoples have a significant stake in a water management issue. This is readily apparent in the recent spate of cases that have afforded legal status of personhood to rivers (Pecharroman, 2018). For example, several authors have recently described developments in Australia where the idea of "cultural flows" (Johnston et al., 2012; Magdaleno, 2018; Weir, 2009) has taken hold as a complement to orthodox approaches to environmental flows (Jackson, 2017). Similarly, Finn and Jackson (2011) urged researchers to consider Indigenous people's attachments to rivers in environmental flow assessment, specifically Indigenous cosmologies and ethical responsibilities in water governance. The next phase of environmental flows science, heralded by the Brisbane Declaration and Global Action Agenda 2018 (Box 1)—and the renewed definition of environmental flows—represents an opportunity to further these developments, to embrace these alternative views of sustainability, and to better consider the co-constitution of river flows, ecosystems, and society. In the next section, we explore case studies that have advanced our understanding of diverse human relationships with rivers. These cases represent a bridge to an emerging mindset that seeks to recognize and foster mutually beneficial relationships of interdependence between people and rivers, as well as support the full participation of those with a stake in water management decisions.

3 | CASE STUDIES: A DIVERSITY OF RELATIONSHIPS BETWEEN HUMANS AND RIVER FLOWS

There is a growing body of literature, mostly produced in the past decade, responding to the realization that the support of local people—those who most directly experience the effects of river alterations—is necessary if the goals of sustainable water management are to be met (Conallin, Dickens, Hearne, & Allan, 2017; Kabogo et al., 2017; Lave, 2016). Attention within water governance to public participation and more generally to the importance of process coincided with changes in human rights law that have influenced international standards relating to community consent to water resource development. Two high profile international institutions have focused particular attention on the needs of Indigenous peoples who have suffered human rights violations and disproportionate negative impacts of large dams (Carino & Colchester, 2010; Estes, 2017; Robison et al., 2018). Reporting in 2000, the World Commission on Dams helped establish as development best practice the requirement to respect the right of Indigenous peoples to give or withhold their "free, prior and informed consent" to development projects (Carino & Colchester, 2010). Almost a decade later, the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) affirmed the rights of Indigenous Peoples to "maintain and strengthen their distinctive spiritual relationship with their traditionally owned or otherwise occupied… waters" (Article 25 cited in Robison et al., 2018, p. 856). The Declaration also imposed obligations on nation states to seek the free, prior and informed consent of Indigenous communities to water resource developments affecting them.

With this societal change in norms, it is becoming ever more important to satisfy the flow needs of riparian human populations dependent on rivers for their livelihood and well-being in setting environmental flow recommendations. This is a change from earlier considerations of human linkages to river flows, which focused heavily on recreational uses of rivers or scenic beauty (e.g., Brown et al., 1991). More recent studies have documented the linkages of river flows to floodplain agriculture, transportation, and social exchange, and to acts of reverence, cultural identity, or sense of place (see, e.g., Table 1; Figure 1).

In this section, we examine case studies from around the world that exemplify the more integrative conceptualization of environmental flows articulated in the Brisbane Declaration 2018. In that manifesto, environmental flows and aquatic ecosystems "*support human cultures, economies, sustainable livelihoods, and well-being*" (Arthington et al., 2018; Box 1) and therefore need to build upon local ways of seeing and understanding rivers to protect not only well-established relationships, such as floodplain fisheries, but also the less visible and generally less easily quantifiable values of rivers in water resource allocation frameworks. Additionally, the selected cases offer a lens for a better understanding of power relations among stakeholders and the importance of trust in supporting and developing dynamic relationships between humans, river flow regimes, and aquatic ecosystems, through relationships that are sustainable, just, and inclusive.

3.1 | The Patuca River, Honduras

The Patuca River, Honduras, is Central America's third longest river and supports Indigenous Miskito and Tawahka who depend on it to sustain their lifeways. Additionally, the Patuca River is a primary conduit for transportation and communication in eastern Honduras, as much of its basin drains roadless areas. Since the 1970s, the national government has considered numerous hydropower projects. In 2006–2008, during planning for the Patuca III hydropower project, environmental flows were assessed under an agreement between The Nature Conservancy (TNC) and the Honduran National Electric Energy Corporation (ENEE) (see Esselman & Opperman, 2010 for a summary).

Scant published data on the ecology of the Patuca River were available to the environmental flows scientific team at the time of the assessment. Researchers sought to fill knowledge gaps by working with Indigenous Miskito and Tawahka. A diverse team of ecologists, hydrologists, and community members collected and systematized information for setting flow recommendations in workshops. Interviews with boat captains along the Patuca River linked low waters to extended travel time, increased risk of accidents, and associated costs. During workshops, Miskito and Tawahka community members annotated maps and photos to define river water levels important for key ecological components (e.g., fish, crocodile habitat), for vital social components (e.g., transportation, fishing), and for extreme events (e.g., Hurricane Mitch in 1998). External researchers relied on Indigenous knowledge of the river to form hypotheses about flow-dependent ecological characteristics of the Patuca River and to help them identify social factors that could be vulnerable to flow alterations (Esselman & Opperman, 2010).

The process of establishing flow recommendations to ENEE for the operation of the Patuca III hydropower project focused on: (1) channel morphology; (2) aquatic organisms; and (3) terrestrial resources, human communities, and riparian forests. Researchers considered the reliance of Miskito and Tawahka communities on the Patuca River for transportation in flow recommendations, as well as the requirements for floodplain conditions to support agriculture and fisheries. Having identified the most challenging passage points for boat traffic, researchers estimated the flow levels above normal dry-season base flow level required to minimize barriers to river passage. The recommended flow rate was similar to the predicted mean outflow from the dam during normal dry-season operation.

The Patuca River case exemplifies incorporation of human dimensions in environmental flows in multiple ways. First, it involved a multidisciplinary team from diverse institutions and backgrounds, including numerous Indigenous people from the lower basin. Second, it relied primarily on local knowledge of Miskito and Tawahka peoples for understanding of flow-dependent ecological and social features of the Patuca River. Third, human dependencies on the flow dynamics of the Patuca River—for transportation, communication, floodplain agriculture, and fisheries—were incorporated as environmental flow recommendations.

3.2 | The Ganga River, India

Millions of people consider India's Ganga (Ganges) River sacred. Religious Hindu texts describe the river/goddess as: "*turbulent, sportive, moving, swift, leaping and booming*" and the River *Ganga* derives its name from the Sanskrit verb gam, meaning "to go" (Eck, 1982). Over millennia, people throughout India have developed customs, rituals, and philosophies that reflect and align with the natural rhythms of the river. People depend on the Ganga for water for daily drinking and washing. Rituals such as ceremonial bathing and meditation, and traditional practices such as flood recession farming are critical to the maintenance of cultural identities. These uses of the Ganga were historically based on the availability of certain flows at different times of the year. (Lokgariwar, Chopra, Smakhtin, Bharati, & O'Keeffe, 2014). People living beyond the basin also engage in some of these practices. For example, the Kumbh ceremony represents the world's largest aggregation of people for a religious purpose. In 2013, over 80 million devotees visited Allahabad, India, to drink from and immerse themselves in the Ganga River to attain salvation (WWF, 2013). The event's significance was linked to high public expectations for adequate and clean flows in the Ganga during the celebration (Sarkar, 2017).

Appreciating this context, environmental flow assessments undertaken by World Wildlife Fund (WWF) and partners for the Ganga River have focused on documenting and better quantifying socio-cultural relationships to flow, using the Building Block Methodology with inclusion of a component on cultural water requirements (Lokgariwar et al., 2014; Figure 2). Review of historical and religious texts and participatory surveys and interviews with riverside human communities provided valuable information on the symbolic importance of the Ganga River locally and to the wider nation of India. Responses indicated that the built environment provided a means for record-keeping of historical flows, with temples and ghats (steps) marking levels of flow events. Interviewees frequently expressed cultural flow requirements with reference to depths at these sites and along banks, but also in terms of the width and depth of the Ganga channel. Using hydraulic cross-sections, the depths and widths required for cultural practices in different parts of the channel were converted into environmental flow requirements.

To complete the environmental flow assessment, levels of water necessary for worship, ritual bathing, and cremation rites were estimated under three scenarios: (a) flows for maintenance years (neither too wet nor too dry); (b) flows for drought years; and (c) flood flows for both

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maintenance and drought years. This was followed by an assessment of flow needs for a successful Kumbh in 2013. Here too, a review of texts and interviews with elders, religious leaders and visitors to the key bathing sites collected data on the desired water depth, water surface width, and velocity of the river at key bathing sites for two scenarios: (a) during the entire 12-week Kumbh and (b) during the special Snans (bathing periods) scheduled for six nonconsecutive days (WWF, 2013).

Non-negotiable water depth levels were recommended for the Kumbh festival, as was a restriction on discharges of untreated waste into the Ganga River. These flow recommendations aligned well with geomorphological and biological objectives of the environmental flow assessment (WWF, 2013). In response, the state government of Uttar Pradesh agreed to allocate an additional 200–300 m^3/s for the two-month duration of the Kumbh festival (Lokgariwar et al. 2014). During 2013, monitoring efforts showed that recommended water levels were maintained for more than 90% of the festival's duration. To the best of our knowledge, the Ganga River case was a world first in giving the spiritual status of a river the highest priority for determination and implementation of environmental flows. The magnitude and importance of the celebration of the Kumbh in 2013 called for action on environmental flows, and presented an opportunity to highlight the conservation challenges facing rejuvenation of the larger Ganga Basin (WWF, 2017).

3.3 | The Athabasca River, Canada

The Athabasca River, Canada, is linked intimately to the culture and economy of the Athabasca Chipewyan First Nation (ACFN) and Mikisew Cree First Nation (MCFN). The rights of these First Nation peoples to hunt, trap, fish, and otherwise exercise their rights—all activities linked to the Athabasca River and the Peace-Athabasca Delta, a massive wetland complex (Timoney, 2013)—were recognized in Treaty No. 8 of 1899. Candler, Olsen, and DeRoy (2010) documented the relationships of the ACFN and MCFN to the river, including their concerns over navigation and broader water quality and quantity issues related to their practice of Treaty rights. Their study aimed to understand the possible effects of river alteration to the practice of Treaty rights, such as limited access, reduced quality of lands or waters for subsistence use, and erosion of opportunities for transmission of knowledge. Beyond the functional uses of the river for mobility and economic practice, for First Nations the Athabasca River is a sentient being whose liveliness drives the flow of water through the area, as indicated in a comment from an ACFN representative:

> "When we were younger the Athabasca River was … a wild beast. In other words, because it was alive, it had tremendous amount of water, it fed all the tributaries, lakes and everything. When the spring flood and that occurred … it brings life to the delta and when it brought life to the delta it also kept our people healthy, our population stable and, in other words, it sustained our way of life for our people for the existence of who we are today."
>
> (Candler et al., 2010, p. 12).

The 2010 study was conducted in the context of ongoing upstream oil sands development, a changing climate, and overall declining flows (Sauchyn, St-Jacques, & Luckman, 2015). Candler et al. (2010) found that reductions in the quantity and quality of the Athabasca

River's flow associated with oil sands development were having adverse effects on the ability of ACFN and MCFN members to access territories, and to practice their Aboriginal and Treaty rights. Interviews with male navigators revealed that use of the river for drinking water, trapping, and teaching seemed to have declined more than use for hunting, transportation, and cultural/spiritual and wellness practices. All respondents reported that the seasonal flow of the Athabasca had changed over their lifetimes.

Based on these findings, researchers advanced environmental flow recommendations in the form of two preliminary thresholds. The first threshold, an Aboriginal Base Flow (ABF), recommends water levels for the Athabasca River and adjacent streams that allow ACFN members to fully practice their rights and access their territories. The second, an Aboriginal Extreme Flow (AXF), defines a low water level for the river below which loss of access would cause widespread disruption of Aboriginal and Treaty rights along the river, its tributaries, and the delta. Based on recollections of land-users and the normal year hydrograph of the Athabasca River, researchers made conservative estimates of flow conditions for the ABF and AXF. The study recommended that the Crown "sit with" both Nations to establish an Athabasca River Consultation and Accommodation Framework to govern future water management. This governance model would include: linking water abstraction activity to the duties of the Canadian Government under the treaty to both consult and accommodate First Nations, setting a goal for frequency of spring floods and further monitoring and refinement of AXF levels and their social and ecological impacts (Baines, Steelman, & Bharadwaj, 2017).

The Athabasca River case is emblematic of the widening of scope of environmental flows in its explicit recognition of the flow definitions and needs of First Nation peoples of Canada. Even the names of the recommended flows—Aboriginal Base Flow and Aboriginal Extreme Flow—leave little doubt regarding the intended beneficiaries of these water management guidelines. The ability to practice Aboriginal rights, as recognized in a historic Treaty, and the well-being of First Nation peoples in the Athabasca River are dependent on river flows (Baines et al., 2017). Additionally, the Athabasca case represents an attempt to account for Indigenous worldviews and the quality of people-place relationships, a challenging task for environmental flow assessments (Finn & Jackson, 2011).

3.4 | Murray-Darling Basin, Australia

During the past few decades there has been a significant investment in scientific research to inform environmental flow assessments in Australia, including experimentation in approaches to determining the flow requirements of Indigenous peoples (Jackson, Pollino, Maclean, Bark, & Moggridge, 2015). Indeed, Indigenous leaders have initiated research into "cultural flows", a concept which they define as "*water entitlements that [would be] legally and beneficially owned by the Indigenous Nations of a sufficient and adequate quantity and quality to improve the spiritual, cultural, environmental, social, and economic conditions of those Indigenous Nations*" (Weir, 2009).

Jackson et al. (2015) describe two multidisciplinary case studies conducted in Australia's Murray–Darling Basin to understand Indigenous values and explore the application of methods to derive water requirements to meet them. Participants shared their water values with researchers who quantified a limited set of water requirements necessary to sustain those values and then assessed whether these water requirements would be met under three alternative water management scenarios, one of which would entail a substantial reallocation of water to the environment.

The first case concerns the Werai State Forest, part of the Murray River complex of wetlands recognized under the Ramsar Convention. The Werai is described as a special place for Wamba Wamba people: it is a place "*seen by most of the local community as home*" (Jackson et al., 2015, p. 146). There are 349 registered Aboriginal cultural sites in the forest (Yarkuwa Indigenous Knowledge Centre Aboriginal Corporation, 2009). Title to the Werai Forest is due to be handed back to the Wamba Wamba and the area is to be managed as an Indigenous Protected Area. Restoring "cultural water" to the wetland is a priority of the community (Weir, Ross, Crew, & Crew, 2013). Threatening this goal, however, are changes in the frequency and duration of flooding of the Werai forest due to alterations to land use and river regulation. Concerned about the poor condition of the forest, traditional owners told researchers that they sought a more consistent delivery of environmental water under a flow regime that restores a balance in vegetation communities and provides suitable habitats for fish and waterbirds. The results of this preliminary investigation have been used by traditional owners in their discussions with the Commonwealth agency that delivers environmental water to features of ecological significance, along with a private group that brokers environmental water delivery to wetlands.

The second case, from the northern Murray–Darling Basin, concerned a small *billabong* (oxbow lake) that fills periodically during flood flows and the nationally registered heritage fish traps at Brewarrina on the Barwon–Darling River. Prior to European settlement, the billabong area was an important tribal meeting place. Between 1876 and 1967 it was the site of the Brewarrina Aboriginal Mission and it is now listed on the State Heritage Register. Environmental protection is a priority for the Ngemba people that maintain rights and responsibilities to their territories. Sites of spiritual significance represent important sources of cultural inspiration while also providing opportunities for recreational and subsistence pursuits, such as fishing and collecting bush foods. Two elders described why these places are special to them and their responsibilities to the river and its life: "*all legends, stories are along the river, for example where the billabong meets the river: it's where the spirits are*" (Jackson et al., 2015, p. 147). Further, the heritage fish traps, as well as various other sites along the river provide evidence of past occupancy. Ngemba traditional owners stated that water needed to be allocated to sustain the "life force" flow of the river, to connect the billabong to the river at times of high flow, and to enable local sustainable development enterprises. According to Ngemba participants, changing flow regimes were the main causes of decreasing water quality and habitat loss. Researchers employed semi-structured interviews, workshops, photo voice elicitation and mapping methods to define a set of hydrologic requirements that quantified an acceptable flow regime or particular flow demands (Jackson et al., 2015).

These preliminary studies demonstrate how Indigenous knowledge, values and priorities can contribute to the setting of water requirements in the Australian context. They demonstrated the potential for environmental flow assessment methods (Finn & Jackson, 2011; Poff et al.,

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2010) to address direct Indigenous uses of water. Nevertheless, further discussion is required among Indigenous communities, water planners, and eco-hydrology specialists to extend these methods to meet a wider array of less tangible Indigenous values.

3.5 | Kakaunui and Orari rivers, New Zealand

Maori, the Indigenous people of New Zealand, have developed many innovative approaches to the comanagement of freshwater (Harmsworth et al. 2016). Cultural Flow Preference Studies (CFPS) offer one approach that has been implemented across New Zealand to convey to decision makers how flow regimes affect Maori cultural interests (Tipa & Nelson, 2008; Tipa, Nelson, Home, & Tipa, 2016). A CFPS represents a different way of thinking about the role of people in the setting of environmental flows, and a new way of conceptualizing how people react to rivers. It recognizes that people view a landscape and make judgments concerning the type and quality of experiences they expect to have and the ease of accessing, exploring, using and functioning in the environment they are viewing (Chenge, 2007; Kaplan & Kaplan, 1982).

To develop the CFPS approach, Maori provided descriptions of river flows, river use, and the attributes that describe healthy vibrant rivers that support cultural beliefs, values, and uses (Figure 3). From these descriptions, valued flow attributes formed the basis for field assessments. Cultural assessments of sites identified by Maori utilize a process akin to customer satisfaction assessments and environmental preference studies (Tipa, 2010). Cultural flow preferences, and importantly the flow thresholds, are calculated for four themes: *mahinga kai*—gathering of foods and other materials for cultural use (up to nine attributes); *Wai Maori*—freshwater (four attributes); *hauora*—well-being (three attributes), and cultural landscapes (three attributes).

We describe results of CFPSs in the Kakaunui and Orari river catchments in New Zealand (Tipa & Nelson, 2012a, 2012b). Through field visits, structured assessments, and observations, average scores for various flow attributes and for each of the four themes (i.e., Wai Maori, Cultural Landscape, Cultural Use, and Hauora) were determined at several sites in each catchment. These average scores were compared with average recorded river flows for the time and date of the assessment. Additional data were collected using experiential study methods, specifically personal interviews with tribal members, focus groups, the use of pictorial information, open ended questions, and cognitive mapping.

For the Kakaunui Catchment, the data confirmed that flows for one site in the Kakaunui Catchment (at Mill Dam) at or below 350 L/s were consistently scored as being unsatisfactory across all four themes. However, assessors also rated flows between 350 and 650 L/s as unsatisfactory and of concern for at least one of the themes. These initial analyses that consider the ratings for satisfaction and a weighting for the significance of each attribute suggested that the current minimum flow of 250 L/s could be considered too low by Maori (Tipa and Nelson 2012b). In the Orari River, the data suggested that Maori were highly unlikely to support a flow of less than 900 L/s because flows below this level exposed the riverbed, led to the accumulation of nuisance plants, and impeded fishing from Maori lands (Tipa and Nelson 2012a).

Flow conditions impact how Maori feel about a site. As *kaitiaki* (guardians), Maori are expected to ensure healthy condition of sites within their territories are available for all to engage with safely. However, when flows in the Kakaunui River were below 350 L/s for prolonged periods, Maori believed that the health of the sites prevented use; they did not believe that there was a good feel to the sites, and they were not proud of the condition of the sites. These feelings impact their cultural well-being. Maori also acknowledge a minimum flow is only one aspect of the flow regime. A range of flows, their timing, and duration all help determine whether or not a site supports cultural use and sustains ecosystems. Therefore, the flow assessment process is necessarily a partnership combining the expertise of biophysical and other scientists with the intimate knowledge and experience of Maori (Tipa & Severne, 2010).

4 | DISCUSSION

The above-mentioned cases represent early efforts to recognize, prioritize and incorporate the social and cultural importance of river flow regimes in environmental flow assessments. The purpose of this incorporation is to improve water management and governance by connecting human communities, satisfying spiritual and religious needs, and protecting Indigenous rights and well-being, in accordance with international human rights standards. Nevertheless, these cases only scratch the surface of the multitude of relationships between humans and rivers and the opportunities for incorporating them into environmental flows. We encourage further exploration of still under-recognized or hidden river flow values and dependencies. Examples might include the linkages between a river's flow and: a sense of place, identity, subsistence resources, religious and ancestral belief systems, well-being, language or locally important narratives, and education practices, among others (Table 1; Figure 4). We also urge wider acceptance and more explicit inclusion of diverse knowledge of rivers, not only limiting flow assessments to forms of expertise based on the hydrograph as the main framing principle. There are many examples of other ways of knowing or seeing rivers that are insightful for developing more sustainable and just interactions between societies and rivers. In the Amazon, rivers are central to the worldviews of Indigenous communities. Amazonian rivers can include features such as underwater cities which provide shelter to drowned relatives (Fraser & Tello Imaina, 2015) and can sustain ancestors who protect water resources and whose existence is also influenced by flow (Huertas & Chanchari, 2011). In north Australia, many Aboriginal traditions affirm the role of the Rainbow Serpent as driver of the hydrological cycle and bringer of the wet season floods (Liedloff et al., 2013). In Africa, there is widespread belief in river Gods and spirits that have their own water requirements, often related to deep pools of clear water or waterfalls; these Gods can be angered by changes to flow regime through water infrastructure (Breen, Jaganyi, Tham, & Zeka, 2006; Main, 1990; Siegel, 2008).

In these and other water knowledge and management traditions, riparian communities are keen to hold on to their custodial rights and responsibilities and would like to maintain their relationships with each other and with the river. How to reconcile such desires with national policies and legislation is still very much an open question. Further, a movement to recognize rivers as agents with lifegiving force and personality has taken hold in Colombia, New Zealand, and India (Pecharroman, 2018). Granting legal personhood to rivers foregrounds reciprocal exchanges between people and rivers, emphasizing mutual responsibilities over narrow utilitarian definitions of human benefit from water and resource extraction (O'Donnell & Talbot-Jones, 2018). These new frontiers of water governance represent promising avenues for improving the assessment and implementation of environmental flows within the blueprint of the renewed Brisbane Declaration and Global Action Agenda (Arthington et al., 2018).

The cases described in this paper illustrate opportunities for the adaptation of existing environmental flow methodologies to achieve greater consideration of river-human relationships, but also underscore the relevance of new approaches that use social and cultural perspectives for framing sustainable ways of living with rivers that can perhaps complement or partly replace typical environmental flow assessments. These cases are also consistent in underscoring the need for interdisciplinary teams that include social scientists so as to draw on their knowledge and methods. Notwithstanding those advances, the majority of environmental flow approaches still retain a modernist ontological framing, one in which scientific knowledge defines the river as a natural or biophysical entity that can be objectively known. Cultural values and social relations appear at best as additional factors or dimensions that need to be incorporated in the biophysical framing of environmental flow assessments. In this prevailing framing, alternative (nonmodern) ways of engaging with, talking about, living with and indeed defining and knowing rivers are relegated to the realm of "culture."

For the science and practice of environmental flows to advance according to the internationally-agreed definition and actions recommended in the 2018 Brisbane Declaration, there is a need for increased acceptance that the production of scientific knowledge about rivers is itself also a social and cultural process (Johnston et al., 2012; Magdaleno, 2018). All scientific concepts are partial and historical, as Poff and Matthews (2013) acknowledge in their history of the evolution of environmental flows. In developing the natural flow paradigm (Poff et al., 1997), an idea that has provided a solid conceptual basis for environmental flows, river flow was seen as one of many significant environmental variables but it came to be considered the "master variable" governing river ecosystem characteristics and functions. In another sense, flow was seen as a 'master variable' in the era of widespread dam construction, for it could most readily be controlled or "mastered" with the know-how of scientists and engineers and through the infrastructure that harnessed the power of water.

Realization of the renewed Brisbane Declaration (Box 1) requires a rethink of relationships between humans and rivers. A crucial step will be for researchers and water managers to reflexively acknowledge the diversity of ways of knowing, relating, and utilizing rivers, to move towards more locally or contextually situated assessments and negotiations of environmental flows. This will lead to better recognition of the mutual interdependencies between humans and rivers, and support the development of effective approaches to foster more mutually beneficial modes of relating to rivers in situations where water extraction and river regulation threaten to undermine the health of rivers and their dependent human communities. Achieving this requires that assessment and negotiation processes allow sufficient time for full inclusion of all interests and for disempowered groups to be afforded opportunities to influence project scope and methods. The Brisbane Declaration's accompanying Global Action Agenda offers guidance for continued advancement towards incorporation of river-human relationships in environmental flows, through recommendations for leadership and governance, management, and research. The greatest challenge may be to deepen, pluralize and diversify understandings of the relationships between humans and rivers, and place the acceptance that there are many different ways of seeing and knowing rivers at the core of environmental flow assessments and their implementation.

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BOX 1

THE BRISBANE DECLARATION AND GLOBAL ACTION AGENDA ON ENVIRONMENTAL FLOWS (2018)

In 2018, scientists, river conservationists, and water managers revisited the Brisbane Declaration and Global Action Agenda of 2007. In the decade between the first and second declarations, the environmental flow community had come to appreciate that "social and cultural dimensions of environmental flow management warrant far more attention" (Arthington et al., 2018, p. 2). Thus, a significant new element of the 2018 Declaration and Global Action Agenda is the emphasis given to "full and equal participation for people of all cultures, and respect for their rights, responsibilities and systems of governance in environmental water decisions" (Arthington et al., 2018, p. 12).

The Declaration sets out six statements, all pertinent in the context of this paper:

1. Environmental flows are essential to protect and restore biodiversity, aquatic ecosystems, and the ecosystem services they provide for all societies.
2. Environmental flows are critical to protect and safeguard the world's cultural and natural heritage.
3. Environmental flows have been compromised and today many aquatic systems around the world are at risk.
4. Implementation of environmental flows requires a complementary suite of policy, legislative, regulatory, financial, scientific, and cultural measures to ensure effective delivery and beneficial outcomes.
5. Local knowledge and customary water management practices can strengthen environmental flow planning, implementation, and sustainable outcomes.
6. Climate change increases the risk of aquatic ecosystem degradation and intensifies the urgency for action to implement environmental flows.

The Action Agenda contains over 30 recommendations to support and advance environmental flow implementation organized under the categories: leadership, management, and research. A central recommendation is to "develop and implement a legal basis for regulating water use, environmental flows, water rights, and licenses, including recognition of cultural heritage values, knowledge, and customary relationships with water" (Arthington et al., 2018, p. 12).

The revised Declaration "heralds a new era of scientific innovation, shared visions, collaborative implementation programs and adaptive governance of environmental flows, with ample opportunities for engagement across multiple sectors, disciplines, regions, and cultures" (Arthington et al., 2018, p. 7).

FIGURE 1.

(a) The lives and livelihoods of people across the Amazon are inextricably linked to seasonal fluctuations in river flows. Rivers are also a key component of the culture of many Amazonian Indigenous groups, such as the Shawi (pictured here). (b) Rivers offer spaces, goods, and functions that mediate social interactions. Here, a gathering of canoes in the Peruvian Amazon. Photo credits: Alvaro del Campo, The Field Museum, USA

FIGURE 2.

Flow needs for religious and spiritual practices were central to an environmental flow assessment for the Ganga River, India. Here, a gathering of pilgrims for the Kumbh festival. Photo credit: Chicu Lokgariwar

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FIGURE 3.
(a) A tribal member completing a cultural assessment of a tributary of the Kakaunui River, New Zealand. (Photo: Kyle Nelson). (b) As part of the Kakaunui Cultural Flow Preference Study, tribal members chose to complement their cultural assessments with data about eel presence, collected through electrofishing (Photo: Myra Tipa)

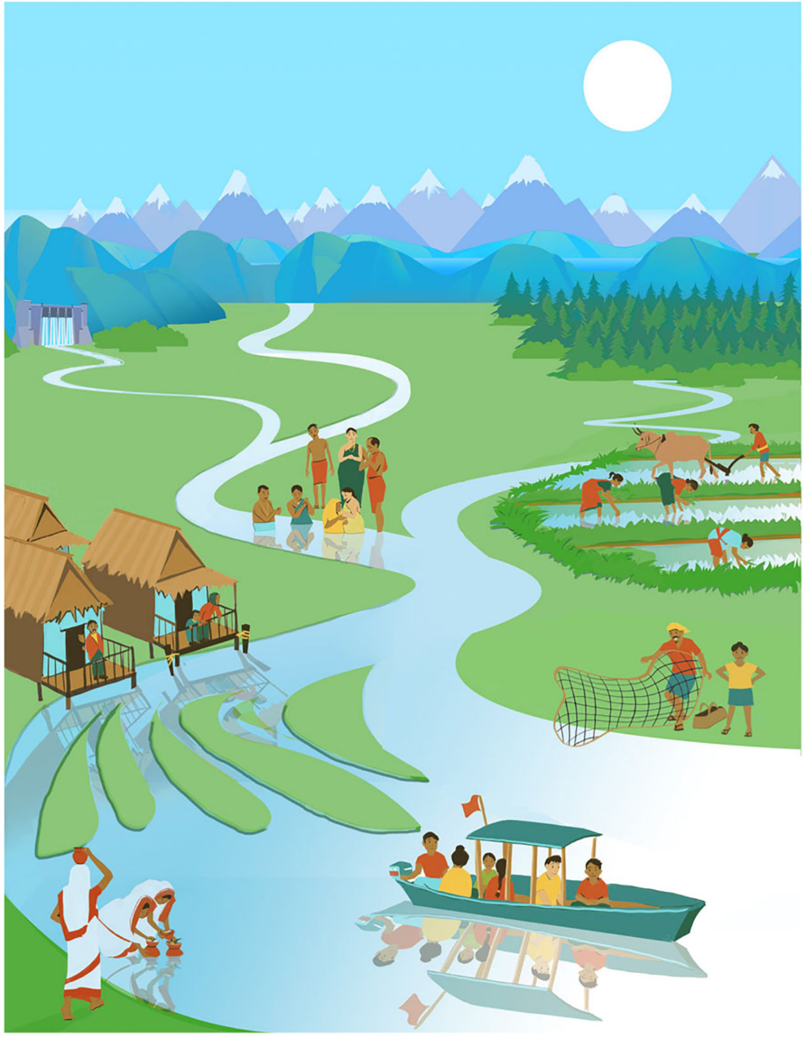

FIGURE 4.

For many human populations around the world, river flows are linked to livelihood, identity, sense of place, religious beliefs and ceremonies, language systems, or educational practices. These embedded, reciprocal, and constitutive relationships between humans and rivers remain poorly understood, but can be critically important to assessment and implementation of environmental flows

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TABLE 1

Select examples of cases and references illustrating various interlinked relationships between humans and rivers from different regions and cultures of the world

Activity/use/value	Details	Example locations	References
Floating agriculture	Crops and vegetables are grown in soilless floating platforms (beds) constructed of locally available materials	Bangladesh	Chowdury and Moore (2017)
Fishing, livestock grazing on floodplains	Floodplain fishing	Rufiji River	Hamerlynck et al. (2011)
		Bangladesh	DeGraaf (2003)
	Dependence on river-floodplain dynamics	Tanzania, Vietnam	O'Keeffe, Graas, Mombo, and McClain (2017)
			Blake etal. (2011)
	Iconic fish species such as salmon	Washington State, USA	Jacob, McDaniels, and Hinch (2010)
	Agriculture, fishing, bush meat, edible plants, etc.	Slave River and delta, NW Territories, Canada	Mantyka-Pringle et al. (2017)
Transportation	Transport for houseboats along rivers	Thailand	Nguyen and Ross (2017)
Cleansing	Force of water in cleaning an area	Northern Thailand	Nguyen and Ross (2017)
Well-being and therapeutic effects	Proximity to the river is calming	Canada	Jacob et al. (2010)
			Montag, Swan, Jenni, and Maule (2014)
	Connection to river and fishing contributes to tribal well-being	Quinalt Indian Nation, Washington, USA	Amberson, Biedenweg, James, and Christie (2016)
Recreational uses	Certain flows suitable for recreational uses such as rafting, canoeing or kayaking	Cheoah River, North Carolina	Dilts (2005)
	Whitewater rafting and definition of boatable days, economic benefit from rafting	Lower Dolores River, Colorado	Fey (2014)
		Trinity Dam, Colorado	Shelby, Brown, and Baumgartner (1992)
	Hiking up rivers	Zion National Park, Utah	Douglas and Taylor (1998)
Festivals and ceremonies and other acts of reverence, associations and kinship with spiritual beings and deities	Annual Kuomboka festival which celebrates the relocation of the king and the Lozi people to higher ground before the onset of the flood season	Barotse Floodplain, Zambia	Cai (2017)
	Ceremonies to invoke rain and rituals to worship and show respect to water deities	Northern Thailand	Nguyen and Ross (2017)
		Parapito River Bolivia	Ortiz, Mendez, Zarzycki, and Alcorn (2008)
	Role of rainbow serpent in driving the flow regime	Kimberley region, Australia	Liedloff, Woodward, Harrington, and Jackson (2013)
	Pulse flow from Colorado River	Mexico, Colorado River delta	Bark, Robinson, and Flessa (2016); Bark, Robinson, Jackson, and Flessa (2017).
Identity, cultural transmission and family and group cohesion	Rivers as a source of cultural continuity	Parapito River, Bolivia	Ortiz et al. (2008)
	Interacting with rivers provides a means to teach young, work together, share food and gear (fishing) and fulfill ethical obligations to nonhuman life	Fraser River, Canada	Jacob et al. (2010)

Activity/use/value	Details	Example locations	References
	The river's role as a barrier to encroachment by settler-colonial governments	Lumbee River, North Carolina, USA	Emanuel (2019); Lowery (2018)
A medium of social exchange (in the physical and metaphysical realm)	Rivers provide a material and symbolic means of communicating, interacting and exchanging goods, ideas, knowledge. A means to build shared values and beliefs within and across communities. Rivers represent capacity for transformation (from life to death and beyond)	Global	Klaver (2012), Johnston, Hiwasaki, Klaver, Castillo, and Strang (2012), Krause and Strang (2016)
		Washington, USA	Montag et al. (2014)
		Bolivia	Ortiz et al. (2008)
Sense of place and time	Cyclical behavior of rivers and seasonal changes are recognizable and valued by people who have formed strong attachments and are affected by the presence/absence and movement of water—"rhythms of life"	Isoso, Bolivia	Ortiz et al. (2008)
		North Australia	Liedloffetal. (2013)
		Brazil	Harris (1998)
		North Carolina, USA	Emanuel (2019)