# Rivers in History: Systems, Agents, and Places

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## Contents



**Abstract**

Several influential river histories published in the past several decades have used systems-theoretic ideas and language to break down boundaries between nature and culture, between environment and technology, and between the humanities and the natural sciences. These works have served as models not only for historical research on rivers but for research on landscapes and environments in general. At the same time, a number of recent river histories have eschewed talk of systems, instead approaching rivers as historical agents and geographical places. Through a selective survey of recent works in the history of science and environmental history, this chapter offers a critical assessment of the use of systems theory and systems language to understand the entangled natural-cultural histories of landscape features and the Earth as a whole.

**Keywords**

Rivers · History · Hydrology · Geomorphology · Environment · Technology · Systems

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## 1 Introduction

Is a river a system? Is it useful for historians to conceptualize rivers, mountains, coastlines, and other landscape features in systemic terms? What about the Earth as a whole? In recent years, many historians have explicitly or implicitly answered these questions in the affirmative. Systems talk has provided a way of building bridges and blurring boundaries between the natural and the cultural, between the technological and the social, and between the natural sciences and the humanities. At the same time, the translation of contingent and specific historical phenomena into the seemingly universal language of systems has been criticized for underemphasizing difference, decentering power and inequality, and reducing historical agency to a by-product of system dynamics. Nonetheless, there has been little sustained reflection on the implications of adopting systems talk for work in environmental history and the history of the environmental sciences. This chapter uses the historiography of rivers and river science as a starting point for such a reflection.

As dynamic landscape features with complex relations to human economies, societies, political structures, and technological infrastructures, rivers have seemed particularly well suited to analysis in terms of systems. In *Confluence* (2011), for example, Sara Pritchard presents the twentieth-century Rhône River as the epitome of a broader class of "envirotechnical systems," which she defines as "historically and culturally specific configurations of intertwined 'ecological' and 'technological' systems, which may be composed of artifacts, practices, people, institutions, and ecologies" (Pritchard 2011, 19). Importantly, Pritchard argues that the Rhône is not simply influenced or affected by the construction of dams, irrigation canals, power stations, and other sociotechnological systems, rather the river becomes an envirotechnical system in its own right through its relations to these systems (Pritchard 2011, 20). Moreover, the natural and human-made elements of this system influence each other so profoundly that the line between natural and human-made begin to shift and blur. This is not an accident, as Pritchard shows. On the contrary, shifting and blurring the natural/cultural divide to create a particular "envirotechnical regime" (Pritchard 2011, 23) was the explicit project of engineers and politicians seeking to strengthen the French state in the years following World War II.

While its articulation of envirotechnical analysis was novel, Pritchard's *Confluence* was not the first historical work to apply systems-theoretic terms to the study of rivers. Richard White's *The Organic Machine* (1995), in particular, had served as a model for taking a systems approach to the history of rivers and other landscape features since its publication in 1995. In this slim but wide-ranging volume, White seeks to describe historical changes in the human relationship to the Columbia River in a way that does not reinforce the conceptual divide between nature and culture. To do so he develops the concept of the "organic machine," which he defines as "an energy system which, although modified by human intervention, maintains its natural, its 'unmade' qualities" (White 1995, 2). Central to White's natural-cultural vision of the Columbia is a capacious conception of "work" that borrows and expands upon the scientific definition of that term. It is their common capacity to transfer energy from one place to another, White argues, that allows water, fish,

steamboats, and humans to be understood as part of a single system—an organic machine—that bridges the nature/culture divide.

Like many other works of environmental history in the closing decades of the twentieth century, *The Organic Machine* was influenced by a school of ecological science that had emerged under the label of "ecosystem ecology" a few decades earlier. Articulated in the 1930s by the British ecologist Arthur Tansley, the concept of the ecosystem came of age in the USA with the help of the Cold War–era Atomic Energy Commission, eventually becoming central to the discourse of the environmental movement and environmental policymaking (Hagen 1992; Anker 2001; Martin 2018). When environmental history emerged in the USA in the 1970s as a new label for scholarship on the relationship between humans and their material surroundings, ecosystem ecology was at the peak of its influence, and its systems-theoretic view of relationships among living things and their inorganic environments shaped environmental historians' descriptions of nature. In his 1980 book *Land Use, Environment, and Social Change*, for example, White anticipated his later use of systems language by describing Island County, Washington, as a "system" constituted of "[m]en and women, the land and its plants and animals, and the social and economic institutions men had created" (White 1980, 75). Similarly, in *Changes in the Land*, one of the founding texts of American environmental history, William Cronon advocated for the "system-oriented perspective which an ecological approach allows" (Cronon 1983, 13).

That is not to say that all environmental historians wholeheartedly embraced systems talk. Donald Worster, for example, expressed skepticism about ecosystem ecology in *Nature's Economy*, a wide-ranging history of "ecological thought" in the West since the eighteenth century (1977, rev. ed. 1994). In Worster's view, ecosystem ecology's focus on the quantification of flows of energy and matter made it the handmaiden of an "imperial" view of nature as an exploitable resource and an object of human domination. In a subsequent work, *Rivers of Empire* (1985), he reserved the term "system" largely for social and technological systems: irrigation systems, economic systems, systems of government, and so forth. Rivers and landscapes could be and had been subjected to such systems, but for Worster they were not properly viewed as systems in their own right. The term "system" was reserved for things that humans had built, usually for the purpose of dominating nature, and therefore a systems perspective could not, by definition, encompass both the natural and the human-made.

Despite such reservations, historians increasingly embraced systems talk across a wide range of subfields from the 1970s onward. Among historians of technology, for example, the work of Thomas P. Hughes on electrical networks and other large technical systems was particularly influential. In *Networks of Power* (1983), Hughes argued that historians had hitherto focused too much attention on individual machines or devices—the light bulb, the automobile, and so forth—and too little on the systems of which those machines or devices were components, and on the environments within which those systems were designed to function. Hughes' systems approach helped set the parameters of the history of technology in the following decades, while also influencing the emerging interdisciplinary field of

infrastructure studies (Star 1999). By the 1990s, both environmental historians and historians of technology were therefore prepared to see their subjects of study in terms of systems—the former via the adoption of metaphors from ecosystem ecology, the latter via the study of large technical systems. This embrace of systems talk made it increasingly easy for historians to envision both modern human societies and nonhuman aspects of the natural world as components of a single natural-cultural system.

Facilitated by systems talk, the subfield of envirotechnical history emerged in the late 1990s at the intersection of environmental history and the history of technology. While envirotech scholarship over the past several decades has embraced a variety of approaches and conceptual frameworks (for surveys see Stine and Tarr 1998; Reuss and Cutcliffe 2010; Pritchard 2014; Zeller 2017; Pritchard and Zimring 2020), its leading practitioners have drawn heavily on systems language. Examples include Timothy LeCain's argument that "the subterranean mine can best be understood as a hybrid system that combined natural and technological systems" (LeCain 2009, 53); Finn Arne Jørgensen's study of "historical attempts to develop technological and organizational systems that can keep bottles from becoming waste" (Jørgensen 2011, 6); James Morton Turner's "systems-based approach, focused on the interconnected stocks and flows of materials across the natural and built environment" in the history of lead-acid batteries (Turner 2015, 49); Julie Cohn's description of electric power networks as "complex and dynamic envirotechnical systems" (Cohn 2017, 338); and Jeremy Vetter's study of field science in the US West as a product of "intertwined environmental and technological systems" (Vetter 2016, 5).

As these examples suggest, the language of systems has been central to the way historians have attempted to integrate the study of technology and environment under the rubric of envirotech. Indeed, the very existence of this subfield of historical scholarship arguably rests on the commensurability between nature and technology that has been established by viewing both as systems of a particular sort. The implications of adopting this perspective have, however, largely gone unexamined. Rivers, because they have served as paradigmatic examples, provide an especially suitable subject for exploring these implications. Has viewing rivers as systems placed constraints on the kinds of questions or themes that have historians pursued? Where does the very idea of rivers as systems come from, and what are the alternatives? These questions are especially important to ask at a time when integrated systems models of Earth and human society are being advocated across the natural and human sciences.

## 2 How Rivers Became Systems

Historians of science have rarely singled out rivers as a subject of study, instead situating the study of rivers in relation to broader themes in the history of the Earth sciences. There is a rich literature, for example, on theories of the Earth proposed by European naturalists in the early modern period, in which the subject of rivers figured prominently. The question for early modern naturalists was, on its face,

simple: Where did the water in rivers come from, and where did the water that rivers deposited into the oceans go? As Yi-Fu Tuan (1968) and others have documented, the answers offered were various, but by the end of the seventeenth century a consensus had emerged that water was neither created nor destroyed but rather recirculated in some fashion from the oceans to the sources of rivers and streams. This emerging consensus was linked to natural-theological speculations about the formation and functioning of the Earth by authors such as Thomas Burnet and John Ray (Tuan 1968; Rappaport 1997; Barnett 2019). Two pathways were generally proposed for the recirculation of water: one via evaporation from the oceans and precipitation over land, and the other via subterranean channels that brought water inland in liquid or vapor form. In the eighteenth century, partly as a result of empirical studies showing that precipitation was sufficient to supply rivers—along with a lack of empirical studies demonstrating subterranean circulation—the former became widely accepted. As a number of scholars have argued, this was the period when the concept that would later become known as the "hydrological cycle" was born (Tuan 1968; Biswas 1970; Linton 2010).

Historians of science have also examined research on rivers as part of the history of geology in the eighteenth and nineteenth centuries, when the identification and sequencing of geological strata became central to the emerging discipline (Greene 1982; Rudwick 1985; Secord 1986). Here the focus shifted from flows of water to the sediments that such flows were capable of transporting. Erosion and deposition were among the phenomena at the heart of the catastrophism-uniformitarianism debate, which pitted advocates of sudden, dramatic change in the geological history of the Earth (as might be caused by catastrophic flooding) against advocates of slow, incremental change (as might be caused by the ordinary flow of a river). Catastrophists could build on several centuries of research into the Noachian flood, as described in the Bible, to support their claims that the Earth's surface had been primarily shaped by sudden convulsions. For a mid-nineteenth-century uniformitarian such as Charles Lyell, however—building on the earlier work of James Hutton and John Playfair—stratigraphic evidence suggested that change had been gradual, effected by processes visible to the geologist in the present (Sepkoski 2020). Rivers were among the most important of the geomorphological and stratigraphic agents responsible for such gradual change.

In comparison to the nineteenth century and earlier, rivers play a much smaller role in the historiography of geology in the twentieth century, which has focused on the rise of geophysics and the development of the theory of plate tectonics (e.g., Oreskes 1999)—themes that, even if they do not exclude an interest in rivers, nonetheless direct attention elsewhere. Instead, twentieth-century research on rivers has been mainly the domain of historians of hydrology, who have often—in contrast with historians of the emergence of the hydrological cycle in the early modern period—been more interested in the implications of river science for practical water management than for general theories of the Earth. Giacomo Parinnello's work on hydrology in the Po River basin in the nineteenth century and early twentieth century is a case in point. Parrinello (2017) shows how the creation of a hydrological monitoring network for the river basin both advanced the understanding of river

science and served the immediate needs of the state, which sought to ensure adequate water supplies and minimize damage from flooding. Other scholars have explored links between water resource management, engineering, and river science in other national and colonial contexts (e.g., Reuss 1998; D'Souza 2006; Ertsen 2016; Macfarlane 2020).

The story of how scientists came to conceptualize rivers as systems follows directly on this history, but it is a story that to date has received little attention from historians of science. Instead, the history of river science in the twentieth century has largely remained the domain of scientists reflecting on the history of their own fields, often in ways that focus narrowly on theories and techniques. These scientist-historians have situated the history of rivers not mainly in relation to geology or hydrology, per se, but rather in relation to a field which combines elements of both—namely geomorphology, the study of the Earth's surface and the forces that shape it, among which flowing water is one of the most important (Tinkler 1985). For these historians of geomorphology, the study of rivers was a central locus for a dramatic transformation of their discipline in the mid-twentieth century, when qualitative, evolutionary models of landscape development were replaced by quantitative, systems-theoretic models heavily influenced by hydraulic engineering and thermodynamics. It was this shift, concentrated in the decades immediately following World War II, that introduced the idea of the river as a thermodynamic system—that is, a system that can be characterized in terms of transfers of energy.

Initially studied largely by partisans of this development, this history has both been critiqued by scientist-historians who question its assumptions (Sack 1991, 1992) and, more recently, situated in broader social context by historians of science and STS scholars (Lave 2012; Parrinello 2017). Their work has questioned the characterization of this shift as revolutionary, noting its deep roots in the history of the Earth sciences and the management of river systems and its incomplete adoption and multiple revisions since the mid-twentieth century. Nonetheless, there are clear connections between the changes documented in the history of river science and broader shifts in the Earth and environmental sciences during this period, when systems approaches were widely adopted. The history of Cold War–era ecosystem ecology is perhaps the best studied example (Hagen 1992; Bocking 1997; Coleman 2010; Martin 2018); other examples include climate modeling (Edwards 2010) and Earth system science (Steffen et al. 2020). Taken together, these works show that the Earth sciences also had their "age of system" (Heyck 2015), which in many ways continues today. The turn to systems-theoretic approaches to rivers might not have been as revolutionary as its most fervent advocates claimed, but it was certainly a distinctive characteristic of the post-World War II era.

The idea that rivers can be analyzed as engines for performing the work of moving water and sediment—where "work" is understood in the physicists' sense, as the energy transferred from one place to another—emerged from a historical moment when new techniques for the quantitative study of the Earth intersected with a massive expansion of dams and other water engineering works. In the case of rivers, the mid-twentieth turn toward thermodynamics-inspired systems is closely

connected to the boom in water engineering works that took place at the same time. In the USA, where systems-theoretic approaches were pursued most enthusiastically, the period from the 1920s to the 1960s was one of extensive dam construction, as environmental historians have amply demonstrated (Worster 1985; Harvey 1994). As in other parts of the world (Evenden 2015; Parrinello 2018), many of these dams were built for power generation as well as water supply, and the engineers who managed them took into account not only fluctuations in consumer demand for electrical power but also natural phenomena such as precipitation, snowmelt, infiltration, and evaporation. They became concerned with what Ashley Carse (2012), writing about the Panama Canal, has described as "nature as infrastructure." Moreover, as hydropower facilities were integrated into larger power networks, water power became fungible with energy generated from other sources, particularly fossil fuels. The growth of irrigation networks, some of them incorporating electric pumping stations, similarly encouraged engineers to approach rivers as components of large technical systems (Fiege 1999).

Published several decades after this scientific turn, White's *The Organic Machine* built on and creatively expanded the systems view of the river, reinterpreting "energy" as something that linked the exertions of laboring human and animal bodies, the flow of water and sediment in the river, and the electricity generated by nuclear power plants, among other things. In a certain sense, this approach was nothing new. As Norton Wise and others have documented (Smith and Norton Wise 1989; Daggett 2019), concepts of energy and work articulated through thermodynamics have provided bridges between the analysis of physical and economic systems since at least the nineteenth century. But the mobilization of these terms for historical scholarship found a new resonance in the 1990s. Perhaps not surprisingly given its origins in the application of an engineering approach to natural phenomena, this way of writing about rivers proved to be a very powerful one for dismantling borders between nature and culture, and for studying the intertwined development of natural and technical systems.

## 3 Rivers as Agents and Places

This way of studying river history has not, however, been the only one that historians have pursued. In fact, a great deal of historical scholarship on rivers in recent decades has declined to adopt a thermodynamics-inspired view of rivers as systems, even as it has largely accepted White's argument that rivers ought to be approached as hybrids of nature and culture (see, e.g., Mauch and Zeller 2008). As Matthew Evenden (2018) has argued, the rapidly expanding field of river historiography since the 1990s has abandoned or transcended some of the preoccupations of White's *The Organic Machine* (1995), including its concern with blurring the nature/culture distinction, its privileging of embodied labor as a way of knowing nature, and—of particular relevance here—its use of flows of energy as an analytical tool. Instead, according to Evenden, much recent work has focused on situating rivers in urban contexts or has used border-crossing rivers as the locus for

comparative or transnational environmental histories. Implicit in this analysis is a further point: that much of this literature approaches rivers not as *systems* but rather as historical *agents* or geographical *places*. Describing some works that take these alternative approaches will help clarify what is distinctive about the systems approach and why some scholars have declined to adopt it.

Much of the recent scholarship on river history eschews systems talk in favor of biographical or life-history approaches that figure rivers as nonhuman agents of historical change. Marc Cioc's *The Rhine: An Eco-Biography* (2002), for example, follows White's example in showing how the Rhine, like the Columbia, had been transformed into an "organic machine" or "techno-river" through a century and a half of human engineering (Cioc 2002, 6, 14). In contrast to White, however, Cioc is not particularly interested in using the language of systems to deconstruct the nature/culture divide. The "biography" of the book's title situates the industrial remaking of the river in the nineteenth and twentieth centuries as an episode in the river's longer life history, whose beginning dates to before the arrival of the first humans in Europe. The Rhine may presently be an organic machine, in other words, but it was not always such, and may yet become something else—and throughout and despite these changes, it will remain the Rhine. This life-history approach contrasts with the systems approach, in which rivers are seen as integral parts of wider socio-technical-environmental systems. Instead, Cioc centers the Rhine as an entity with its own historical identity and agency, and thereby highlights how deeply that identity and agency have been compromised by human intervention. A similar approach can be seen in David Blackbourn's characterization of the development of the Oder River, which is framed as part of a centuries-long (but never quite complete or successful) project of the "conquest of nature" in Germany (Blackbourn 2006).

These histories follow a narrative arc of increasing human domination, but not all histories that emphasize nonhuman agency do so, particularly when they are set in periods other than the modern one. Whereas Cioc's and Blackbourn's stories both end with a human-dominated river that remains under the human yoke even after the folly of efforts at complete domination have been recognized and partly reversed, Ling Zhang's *The River, the Plain, and the State* (2016) positions the Yellow River as an uncontrollable entity with just as much historical agency as society and the state. Focused on the eleventh century, when the Yellow River dramatically shifted its course into the Hebei Plain, Zhang's book describes an agent that (or perhaps *who*) resolutely refused to submit to human domination. Indeed, the Yellow River often seemed to respond to human interventions with indignation and retributive violence. Unabashed about describing the river's actions in anthropomorphic terms, Zhang shows how it resisted and frustrated the imperial aims of the Northern Song Dynasty, pulling it into a "hydraulic mode of consumption" that ultimately undermined the imperial state. Although influenced by American environmental history, Zhang explicitly rejects ecology as a model for historical scholarship because, she argues, "ecological thinking keeps at its ontological core the flow and transformation of some essential matter, such as energy" (Zhang 2016, 15)—a reduction, she argues, that risks misdescribing the emergent, entangled relations among particular historical entities.

As Zhang's study suggests, historians who approach rivers as historical agents have found the relationship between rivers and the state to be of particular interest. In doing so, they sometimes hark back to Karl Wittfogel's work on "oriental despotism," which argued that authoritarian states had been built on a foundation of water control, particularly the organization of large irrigation systems (Wittfogel 1957). Both Zhang and Worster explicitly take up Wittfogel's problematic work and attempt to revise and revitalize it for new purposes. But the theme of rivers and states is a broader one that need not take Wittfogel's environmentally determinist approach either as model or foil. As David Biggs shows in *Quagmire* (2010), the Mekong River resisted a variety of efforts at control from at least the 1860s, when France colonized the river's delta region and began attempting to reengineer it through canals and drainage systems, through the 1970s, when the Viet Minh succeeded in driving out the USA, which by then had its own legacy of failed river engineering projects. The river's agency, in this account, neither builds states nor destroys them; instead, it serves as the occasion for what Biggs, citing one of his historical actors, calls "works of Penelope" (Biggs 2010, 37)—that is, projects with no end.

These and other recent works refuse to conceptualize rivers as systems because doing so, they claim, obscures or misrepresents their historical agency, thereby making it difficult to see both how nonhuman entities have actively shaped history (particularly evident in Zhang's and Biggs' studies) and how human interventions have undermined or compromised their ability to do so in particular historical periods (the focus of Cioc's study, as well as Blackourn's). This reflects an interesting return to environmental history's roots, albeit with a twist. As Paul Sutter has argued, the turn toward hybridity in environmental history marked by the publication of *The Organic Machine* in the mid-1990s was, among other things, an effort to move beyond an unreflective conceptualization of "nature's agency" that had characterized the first wave of American environmental history (Sutter 2013). But for many environmental historians, the replacement of those crude notions of agency with a systems-based approach that threatened to evacuate history of agency entirely was a step too far. Instead of rejecting agency because of its association with a certain kind of liberal subjecthood, they have tried to articulate an alternative notion of "nature's agency" that is relational and emergent (Nash 2005). An example of this move can be found in Roderick Wilson's *Turbulent Streams*, a study of Japan's rivers from the seventeenth century to the early twentieth century that builds explicitly on White's work but also shifts the analytic focus from "systems" to what Wilson describes as "riparian relations" (Wilson 2021, 11).

Another set of river historians has taken a different approach, one that largely sidesteps the question of agency but similarly distances itself from the view of rivers as systems. This approach is fundamentally geographical, and some of it has in fact been written by scholars who identify themselves primarily as historical geographers rather than as environmental historians. This approach considers rivers as places or, sometimes, as connectors or borders between places; it also investigates the history of the imagination of rivers as distinct geographical entities (Cunha 2019). Studies of urban rivers have been particularly prominent in this line of research (see, e.g., Evenden and Castonguay 2012). When the term "river system" is used in this

context, which is not uncommon, it is mainly as a way of referring to a network of streams connected within a single watershed, rather than to any kind of systems-theoretic perspective on rivers. In other words, the word "system," when it appears, is meant to indicate only that a particular river is being studied in relation to other streams. This place-based approach to rivers encompasses much of the work that Evenden (2018) covers in his survey of river historiography, including both urban and transnational river histories, and is part of a broader movement to bring the same level of attention to bodies of water—rivers, lakes, oceans, and so forth—that has long been accorded to solid land.

Whereas the systems approach tends to flatten hierarchies—everything is, after all, part of the same system of cycles, exchanges, and feedback loops—historical scholarship that conceives of rivers as places often brings questions of power and inequality to the forefront. This is the case, for example, in Ari Kelman's study of the New Orleans' waterfront, *A River and Its City* (2003), which shows how various residents of the city have struggled for access to and control over nature and public space from the early nineteenth century to the mid-twentieth century. By approaching the Mississippi River as an urban site, Kelman's book highlights the ways that the river's historical changes—perhaps most dramatically, the floods of 1927—intersect with differences in power among various groups and individuals in New Orleans. As *A River and Its City* documents, following flooding along the lower Mississippi in the spring of 1927, New Orleans' commercial elites decided to dynamite the Poydras levee, some 12 miles downstream of the city, to reduce the chance of an unintentional breach of one of the city's own levees. This decision had catastrophic affects for the poor and sparsely populated river parishes of St. Bernard and Plaquemines, whose residents had no say in the decision. In this way, the city's response to the threat of flooding both reflected and exacerbated the deep differences of power in the community.

A nuanced attention to the way social distinctions and power differentials in a city interact with the physical behavior of a river—or in this case, multiple rivers—is also evident in Debjani Bhattacharyya's *Empire and Ecology in the Bengal Delta* (2018). Like Kelman, Bhattacharyya focuses on the intersection of land and water, including the shifting boundary between the two, but she is particularly attentive to how the very distinction itself, between the city and river, is a subject of historical conflict. Moreover, as the title suggests, *Empire and Ecology in the Bengal Delta* is centrally concerned with the imposition of colonial power over a landscape—or, as she puts it, with "the life of the delta at the intersection of a powerful riverine environment and imperial human intentions" (Bhattacharyya 2018, 38). Under the East India Company in the late eighteenth century, a process of imposing European property law onto the fluid landscape of the Bengal delta was initiated; that process generated a legal and economic framework that then progressively remade the material reality of the delta. This process consolidated some forms of power, Bhattacharyya argues, but also reshuffled hierarchies in the city by generating new sources of wealth and power on newly solidified land.

Viewing rivers as places rather than as systems shifts attention from the functional interconnections between humans and nature—something that these books, building

on earlier scholarship, take more or less for granted—to the ways that power (and not just energy or work) is distributed over space. In doing so, these works contribute to a broader rethinking of power and politics in environmental history. If the first generation of self-identified environmental historians was concerned mainly with showing how humans exercised power over nature, almost always at nature's expense, and the second generation was intent on showing how nature and culture were entangled or hybrid (Sutter 2013), then these works show how power within human communities is structured at least in part by the properties and actions of nonhuman entities. In other words, it is not just that "the conquest of nature . . . will always include the conquest, the domination or exploitation" of some people by others (Williams 1980), or that nature and culture are constitutively entangled. It is also that nonhuman entities and forces—whether the flooding of the Mississippi, the shifting sandbars of the Bengal Delta, or the quagmires of the Mekong—affect which humans have power and how they exercise it. Power and privilege are, in this sense, emplaced in ways that are hard to articulate in a systems approach.

## 4 Conclusion

Is a river a system? Many scientists and engineers since the mid-twentieth century have thought so. And is it useful for historians to follow those scientists in viewing rivers as systems? That question cannot be answered with a simple yes or no. Some historians have undoubtedly found it productive. The systems perspective on rivers has worked as a solvent to break down barriers between nature and culture, metaphorically expanding on thermodynamic and systems-theoretic themes to show how "natural" and "cultural" domains ultimately trade in the same basic currency. For White, that currency was energy, albeit a more expansive conception of energy than that offered by physics (see also Demuth 2019); for other scholars, including Pritchard, the identity of the currency is less explicit, but the argument for viewing "technology as natural" and "nature as technological" (Pritchard 2011, 21–22) suggests that whatever form it may take, the currency is shared. Since the 1990s, viewing rivers and other landscape features as systems, envirotechnical or otherwise, has been one of the most effective tools available to environmental historians for moving beyond the too-easy distinctions between nature and culture that characterized the first wave of scholarship in the field. In that sense, it has certainly been useful for historians to view rivers as systems.

As the very selective survey of river historiography presented above also suggests, however, that strategy has not been universally embraced by environmental historians. If systems talk has been a solvent for nature and culture as they were commonly defined half a century ago, recent scholarship has often tried to precipitate out distinctive entities from the natural-cultural solution, albeit ones that do not neatly line up on either side of the nature/culture divide as it has been conventionally conceived. The biographical or agential approach, for example, may recognize that a river such as the Rhine became a "techno-river" over the course of the nineteenth and twentieth centuries while emphasizing that this is only one episode in a much longer

life history, over the course of which the Rhine has exercised historical agency to various degrees and in various ways. Similarly, the geographical approach may acknowledge the complex web of feedback loops connecting all of the entities in a particular place, but it also tends to emphasize the persistence of certain hierarchies and relations of power, which themselves are constituted by and not merely imposed upon the river. Rivers may be systems, this scholarship suggests, but they are not only systems, and utility of concepts such as organic machine and envirotechnical system may be especially limited for the study of rivers in nonmodern and non-industrialized contexts.

Much of this review has focused on works of environmental history for the simple reasons that self-described historians of science have contributed relatively little to recent river historiography. The scientific disciplines most directly concerned with rivers, including hydrology, geomorphology, and aquatic ecology, have received little attention from modern historians of science, and historians of earlier periods have rarely focused on rivers in their own right. Instead, most recent historiography of the Earth sciences has focused on issues and perspectives that, while they are certainly capable of incorporating rivers, do not center them. One reason is that much of this work has sought to understand how scientists came to construct understandings of the Earth that operate on the largest of temporal and spatial scales—that is, studies of the emergence of planetary and deep-time perspectives (Rudwick 1985; Oreskes 1999; Edwards 2010; Selcer 2018; Barnett 2019). This emphasis is understandable at a moment when humanity's global impacts have become increasing obvious and worrisome. But it has also led historians to neglect smaller scales, as well as the sciences that operate at those scales. Rivers certainly can be and have been studied on the global scale—for instance, in attempts to calculate the total discharge or sediment load of all the world's rivers—but in doing so their specificities as rivers tend to be lost.

River history therefore provides an opportunity for historians of science to approach the history of the Earth sciences anew, at scales and in topologies that are not neatly captured by the global/local dichotomy. In doing so, the systems perspective surely has its place, and historians of science are well positioned to show how that perspective can illuminate the entanglement of environmental and technological systems with systems of knowledge. In fact, some historians of science have begun to call for moving beyond the global/local dichotomy to focus on the "regional" (Vetter 2011) or "meso" (Güttler 2019) scales. Fittingly, the scholars calling for this scalar refocusing have also made envirotechnical analysis central to their work, emphasizing the importance of environmental characteristics of particular regions as well as regional-scale technological infrastructures. At the same time, building on Pritchard's (2011) analysis of envirotechnical systems and regimes, they have expanded the borders of envirotechnical analysis to include the study of what one might call envirotechnical epistemes. Vetter (2016), for instance, has described the particular mode of knowledge production characteristic of the "railroad age" in the US West, while Güttler (2020) has explored the diverse forms of knowledge produced through and about the Frankfurt Airport in the twentieth century. Rivers have not yet been the focus of such work, but—given their scale, their importance,

and the extent to which they have been integrated into human infrastructures—they are very well suited to it. There are also promising and as-yet unexplored opportunities here to connect envirotechnical work on rivers-as-systems to work by historians of science on experimental systems (e.g., Rheinberger 1997).

But a systems approach does not exhaust the ways in which historians of science might yet contribute to river historiography. Viewing rivers as historical agents, for example, opens up a distinct set of questions about the history of knowledge about rivers. Unsurprisingly, the history of science as a field continues to privilege the human knower, understood either as an individual or a member of a larger collective. Over time, the variety of knowers admitted into the historiography has grown, as has attention to the material conditions, resources, and tools required for knowledge to be produced and circulated. In that sense, the heroic liberal subject of a certain kind of progressive history of science has gradually been decentered. Still, historians of science, including historians of the Earth sciences, have been slow to engage with the kinds of arguments presented by environmental historians about nonhuman agency. How do changing envirotechnical conditions shape what is known about the Earth? Can events in the life history of a river—from daily fluctuations in flow to a catastrophic thousand-year flood—redirect not only water and sediment but also the course of knowledge? These questions suggest the potential for a non-anthropocentric history of the Earth sciences that has yet to be written.

Approaching rivers as places also raises questions that are hard to articulate when one approaches them as systems, particularly questions about power and difference. Here, too, historians of science can build on the work of environmental historians while expanding the focus to include the production and circulation of knowledge. Rivers and riverfronts are not just sites where competing interests are pursued and where hierarchies are established and sometimes challenged, they are also sites where various actors produce knowledge, often in competing or even incommensurate ways. Work on civic science, popular epidemiology, community-based science, and environmental justice has shown how the concerns and modes of knowledge production of the people who inhabit a place can differ profoundly from those of scientists who visit such a place solely in a professional capacity (Brown 1990, 1992; Di Chiro 1996, 2008; Fortun 2001; Wylie 2018). How do differences in status and power among groups of people inhabiting riverine landscapes affect the generation and communication of knowledge? River history offers a productive site for exploring that question in dialogue with place-based histories of science (e.g., Galison and Thompson 1999; Kohler 2002; Livingstone 2003).

The language of systems—whether used in a strictly systems-theoretic or thermodynamic sense or in a looser and more colloquial sense—is a powerful way of breaking down borders between nature and culture that today seem increasingly inappropriate for understanding the history of the Earth and the Earth sciences. Systems talk is ubiquitous in the contemporary Earth sciences for good reason; it helps scientists working in a variety of disciplines, on disparate phenomena, and across a variety of scales build models together. And historians who have creatively appropriated and extended that language for their own purposes have shown that it can be similarly useful for humanistic understandings of the planet's past. Envirotech

scholarship has benefited greatly from the adoption of the vocabulary of systems theory; one might even say that the subfield largely owes its existence to that vocabulary, which opened up new ways of bringing natural and technical systems into relation. But it is important to remember that this is just one of several idioms available, and that, like any idiom, it is better at articulating some things than others. Historians of science have much to gain by studying rivers as envirotechnical systems that are also systems of knowledge, but they should not lose sight of the fact that rivers can also be agents and places, and that studying them as such may bring to the surface histories that would otherwise remain submerged.

## References

Anker, Peder. 2001. *Imperial ecology: Environmental order in the British Empire, 1895–1945*. Cambridge, MA: Harvard University Press.

Barnett, Lydia. 2019. *After the flood: Imagining the global environment in early modern Europe*. Baltimore: Johns Hopkins University Press.

Bhattacharyya, Debjani. 2018. *Empire and ecology in the Bengal Delta: The making of Calcutta*. Cambridge: Cambridge University Press.

Biggs, David Andrew. 2010. *Quagmire: Nation-building and nature in the Mekong Delta*. Seattle: University of Washington Press.

Biswas, Asit K. 1970. *History of hydrology*. New York: American Elsevier Publishing Company.

Blackbourn, David. 2006. *The conquest of nature: Water, landscape, and the making of modern Germany*. New York/London: W.W. Norton & Company.

Bocking, Stephen. 1997. *Ecologists and environmental politics: A history of contemporary ecology*. New Haven: Yale University Press.

Brown, Phil. 1990. *No safe place: Toxic waste, leukemia, and community action*. Berkeley: University of California Press.

———. 1992. Popular epidemiology and toxic waste contamination: Lay and professional ways of knowing. *Journal of Health and Social Behavior* 33: 267–281.

Carse, Ashley. 2012. Nature as infrastructure: Making and managing the Panama Canal watershed. *Social Studies of Science* 42: 539–563.

Cioc, Mark. 2002. *The Rhine: An eco-biography, 1815–2000*. Seattle: University of Washington Press.

Cohn, Julie. 2017. Data, power, and conservation: The early turn to information technologies to manage energy resources. *Information & Culture* 52: 334–361.

Coleman, David C. 2010. *Big ecology: The emergence of ecosystem science*. Berkeley: University of California Press.

Cronon, William. 1983. *Changes in the land: Indians, colonists, and the ecology of New England*. New York: Hill and Wang.

D'Souza, Rohan. 2006. *Drowned and dammed: Colonial capitalism, and flood control in eastern India*. New Delhi: Oxford University Press.

da Cunha, Dilip. 2019. *The invention of rivers: Alexander's eye and Ganga's descent*. Philadelphia: University of Pennsylvania Press.

Daggett, Cara New. 2019. *The birth of energy: Fossil fuels, thermodynamics, and the politics of work*. Durham: Duke University Press.

Demuth, Bathsheba. 2019. *Floating coast: An environmental history of the Bering Strait*. New York: W.W. Norton & Company.

Di Chiro, Giovanna. 1996. Nature as community: The convergence of environment and social justice. In *Uncommon ground: Rethinking the human place in nature*, ed. William Cronon, 298–320. New York: Norton.

———. 2008. Living environmentalisms: Coalition politics, social reproduction, and environmental justice. *Environmental Politics* 17: 276–298.
Edwards, Paul N. 2010. *A vast machine: Computer models, climate data, and the politics of global warming*. Cambridge, MA: MIT Press.
Ertsen, Maurits W. 2016. *Improvising planned development on the Gezira Plain, Sudan, 1900–1980*. New York: Palgrave Macmillan.
Evenden, Matthew. 2015. *Allied power: Mobilizing hydro-electricity during Canada's Second World War*. Toronto: University of Toronto Press.
———. 2018. Beyond the organic machine? New approaches in river historiography. *Environmental History* 23: 698–720.
Evenden, Matthew, and Stephane Castonguay, eds. 2012. *Urban rivers*. Pittsburgh: University of Pittsburgh Press.
Fiege, Mark. 1999. *Irrigated Eden: The making of an agricultural landscape in the American West*. Seattle: University of Washington Press.
Fortun, Kim. 2001. *Advocacy after Bhopal: Environmentalism, disaster, new global orders*. Chicago: University of Chicago Press.
Galison, Peter, and Emily Ann Thompson, eds. 1999. *The architecture of science*. Cambridge, MA: MIT Press.
Greene, Mott T. 1982. *Geology in the nineteenth century: Changing views of a changing world*. Ithaca: Cornell University Press.
Güttler, Nils. 2019. "Hungry for knowledge": Towards a meso-history of the environmental sciences. *Berichte zur Wissenschaftsgeschichte* 42: 235–258.
———. 2020. *Alles über das Fliegen: eine politische Wissensgeschichte des Frankfurter Flughafens*. Wien/Berlin: Turia + Kant.
Hagen, Joel. 1992. *An entangled bank: The origins of ecosystem ecology*. New Brunswick: Rutgers University Press.
Harvey, Mark W.T. 1994. *A symbol of wilderness: Echo Park and the American conservation movement*. Albuquerque: University of New Mexico Press.
Heyck, Hunter. 2015. *Age of system: Understanding the development of modern social science*. Baltimore: Johns Hopkins University Press.
Hughes, Thomas Parke. 1983. *Networks of power: Electrification in Western society, 1880–1930*. Baltimore: Johns Hopkins University Press.
Jørgensen, Finn Arne. 2011. *Making a green machine: The infrastructure of beverage container recycling*. New Brunswick: Rutgers University Press.
Kelman, Ari. 2003. *A river and its city: The nature of landscape in New Orleans*. Berkeley: University of California Press.
Kohler, Robert E. 2002. *Landscapes & labscapes: Exploring the lab-field border in biology*. Chicago: University of Chicago Press.
Lave, Rebecca. 2012. *Fields and streams: Stream restoration, neoliberalism, and the future of environmental science*. Athens: University of Georgia Press.
LeCain, Timothy J. 2009. *Mass destruction: The men and giant mines that wired America and scarred the planet*. New Brunswick: Rutgers University Press.
Linton, Jamie. 2010. *What is water? The history of a modern abstraction*. Vancouver: University of British Columbia Press.
Livingstone, David N. 2003. *Putting science in its place: Geographies of scientific knowledge*. Chicago: University of Chicago Press.
Macfarlane, Daniel. 2020. Nature empowered: Hydraulic models and the engineering of Niagara Falls. *Technology and Culture* 69: 109–143.
Martin, Laura J. 2018. Proving grounds: Ecological fieldwork in the Pacific and the materialization of ecosystems. *Environmental History* 23: 567–592.
Mauch, Christof, and Thomas Zeller, eds. 2008. *Rivers in history: Perspectives on waterways in Europe and North America*. Pittsburgh: University of Pittsburgh Press.

Nash, Linda. 2005. The agency of nature or the nature of agency? *Environmental History* 10: 67–69.
Oreskes, Naomi. 1999. *The rejection of continental drift: Theory and method in American earth science*. New York: Oxford University Press.
Parrinello, Giacomo. 2017. Charting the flow: Water science and state hydrography in the Po watershed, 1872–1917. *Environment and History* 23: 65–96.
———. 2018. Systems of power: A spatial envirotechnical approach to water power and industrialization in the Po Valley of Italy, ca. 1880–1970. *Technology and Culture* 59: 652–688.
Pritchard, Sara B. 2011. *Confluence: The nature of technology and the remaking of the Rhône*. Cambridge, MA: Harvard University Press.
———. 2014. Toward an environmental history of technology. In *The Oxford handbook of environmental history*, ed. Andrew C. Isenberg, 227–258. Oxford: Oxford University Press.
Pritchard, Sara B., and Carl A. Zimring. 2020. *Technology and the environment in history.* Baltimore: Johns Hopkins University Press.
Rappaport, Rhoda. 1997. *When geologists were historians, 1665–1750*. Ithaca: Cornell University Press.
Reuss, Martin. 1998. *Designing the bayous: The control of water in the Atchafalaya Basin 1800–1995*. Alexandria: Office of History, U.S. Army Corps of Engineers.
Reuss, Martin, and Stephen H. Cutcliffe, eds. 2010. *The illusory boundary: Environment and technology in history.* Charlottesville: University of Virginia Press.
Rheinberger, Hans-Jörg. 1997. *Toward a history of epistemic things: Synthesizing proteins in the test tube*. Stanford: Stanford University Press.
Rudwick, M.J.S. 1985. *The great Devonian controversy: The shaping of scientific knowledge among gentlemanly specialists*. Chicago: University of Chicago Press.
Sack, Dorothy. 1991. The trouble with antitheses: The case of G.K. Gilbert, geographer and educator. *Professional Geographer* 43: 28–37.
———. 1992. New wine in old bottles: The historiography of a paradigm change. *Geomorphology* 5: 251–263.
Secord, James A. 1986. *Controversy in Victorian geology: The Cambrian-Silurian dispute*. Princeton: Princeton University Press.
Selcer, Perrin. 2018. *The postwar origins of the global environment: How the United Nations built Spaceship Earth*. New York: Columbia University Press.
Sepkoski, David. 2020. *Catastrophic thinking: Extinction and the value of diversity from Darwin to the Anthropocene*. Chicago: University of Chicago Press.
Smith, Crosbie, and M. Norton Wise. 1989. *Energy and empire: A biographical study of Lord Kelvin*. Cambridge: Cambridge University Press.
Star, Susan Leigh. 1999. The ethnography of infrastructure. *American Behavioral Scientist* 43: 377–391.
Steffen, Will, Katherine Richardson, Johan Rockström, Hans Joachim Schellnhuber, Opha Pauline Dube, Sébastien Dutreuil, Timothy Lenton, and Jane Lubchenco. 2020. The emergence and evolution of earth system science. *Nature Reviews Earth & Environment* 1: 54–63.
Stine, Jeffrey K., and Joel A. Tarr. 1998. At the intersection of histories: Technology and the environment. *Technology and Culture* 39: 601–640.
Sutter, Paul. 2013. The world with us: The state of American environmental history. *Journal of American History* 100: 94–119.
Tinkler, Keith J. 1985. *A short history of geomorphology.* London: Croom Helm.
Tuan, Yi-fu. 1968. *The hydrologic cycle and the wisdom of God: A theme in geoteleology.* Toronto: University of Toronto Press.
Turner, James Morton. 2015. Following the Pb: An envirotechnical approach to lead-acid batteries in the United States. *Environmental History* 20: 29–56.
Vetter, Jeremy. 2011. *Knowing global environments: New historical perspectives on the field sciences*. New Brunswick: Rutgers University Press.

———. 2016. *Field life: Science in the American West during the railroad era*. Pittsburgh: University of Pittsburgh Press.
White, Richard. 1980. *Land use, environment, and social change: The shaping of Island County, Washington*. Seattle: University of Washington Press.
———. 1995. *The organic machine*. New York: Hill and Wang.
Williams, Raymond. 1980. *Problems in materialism and culture: Selected essays*. London: Verso.
Wilson, Roderick I. 2021. *Turbulent streams: An environmental history of Japan's rivers, 1600–1930*. Boston: Brill.
Wittfogel, Karl August. 1957. *Oriental despotism: A comparative study of total power*. New Haven: Yale University Press.
Worster, Donald. 1985. *Rivers of empire: Water, aridity, and the growth of the American West*. New York: Pantheon.
Wylie, Sara Ann. 2018. *Fractivism: Corporate bodies and chemical bonds*. Durham: Duke University Press.
Zeller, Thomas. 2017. Aiming for control, haunted by its failure: Towards an envirotechnical understanding of infrastructures. *Global Environment* 10: 202–228.
Zhang, Ling. 2016. *The river, the plain, and the state: An environmental drama in Northern Song China, 1048–1128*. Cambridge: Cambridge University Press.