

The Trouble with Rivers

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Rivers give us a lot, but not without a cost. The biological and physical resources that rivers provide sustain life, culture, and economies. But sometimes rivers rise, move, dry, or simply give in to neglect, destroying what they once sustained. Rivers fuel the human imagination and can serve as powerful symbols that exemplify and inspire environmental stewardship. But when they are burning with industrial waste, choked with sediment, or erased by overexploitation, rivers become equally powerful symbols of our shortsightedness. After all, why would any society threaten its supply of a resource as fundamentally important as fresh water?

Even when there is a strong commitment to protecting and restoring rivers, we often find that there is little consistency in how rivers respond to conservation and restoration efforts. Given time and minimal direct intervention, the physical dynamics of rivers can themselves be effective restoration agents by removing human infrastructure (Evans et al. 2000), reclaiming floodplains (Lorang et al. 2005), and restructuring riparian forests (Merritt and Cooper 2000). In other cases, intensive human intervention may be the only way to restore degraded rivers, resulting in a large amount of effort devoted to developing and assessing methods for river restoration (Mitsch and Jørgensen 2003, Palmer et al. 2005, Roni 2005). But some rivers show no response to the most intensive and expensive restoration efforts (Bernhardt et al. 2005), leaving researchers and managers to guess where they went wrong—too much structure, not enough flow, too many fish, not enough algae?

A large part of the complexity of restoring and protecting rivers can be

attributed to the continuous network structure of these systems. It is this continuity that allows an otherwise pristine reach to be degraded by invasive species that disperse along streams and rivers (Adams et al. 2001, Baxter et al. 2004). Likewise, this continuity can allow rivers and streams in highly developed and industrial areas to maintain ecosystem processes and native biodiversity by drawing from intact headwaters (Meyer et al. 2003, Lowe and Likens 2005).

For these and other reasons, the relationship between human societies and rivers is complex. Three recent books, *Rivers for Life: Managing Water for People and Nature* (Postel and Richter 2003), *Disconnected Rivers: Linking Rivers to Landscapes* (Wohl 2004), and *Keepers of the Spring: Reclaiming Our Water in an Age of Globalization* (Pearce 2004), examine this relationship without shying away from its complexity, while addressing a diverse audience that includes both scientists and the general public. Although the authors focus on different implications of the human relationship with rivers, their willingness to acknowledge that this relationship has significant and diverse cultural, ecological, and economic elements strengthens all three books. I found that the most important source of variation in the success of these books was the ability of the authors to balance the need to place information in context, thereby engaging readers, with the need for structure that links specific information and overarching themes.

The freshwater network

Disconnected Rivers, by Ellen Wohl (2004), begins with a review of the physical characteristics, ecology, and geo-

graphic variability of North American rivers. The next three chapters address the history of human impacts to these rivers, beginning with European settlers and pioneers in the early and middle 1800s, and ending with channelization and dam-building efforts in the middle and late 1900s. The last two chapters discuss the challenges of river rehabilitation and of bringing together public interests and science to protect rivers. Throughout the book, Wohl includes detailed descriptions of the physical and ecological effects of specific stressors (e.g., fine sediment, toxins) and profiles of particularly interesting species that occur in North American rivers.

It is clear that Wohl has a deep understanding of the physical processes that shape rivers, and she provides detailed information on how pollutants such as mercury and pesticides affect river ecosystems and biota. I especially enjoyed reading her account of the history and legacy of placer mining. This section illustrates the amazing industriousness of the miners, measured in the output of gold, alteration of riverbeds, and export of sediment to downstream reaches. Here, Wohl uses maps effectively to show the extent of placer mining in California and other regions of the United States. Another account of the cumulative effects of industrial pollution throughout the 1900s on the Illinois River succeeds in outlining the diverse sources and ultimate impacts of pollutants in freshwater systems. This

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account also conveys the author's justifiable disbelief that we as a society have been so slow in enacting laws to protect our water and ourselves from these toxins. In four of the chapters, Wohl concludes with engaging profiles of the ecology and conservation status of some of North America's more charismatic riverine species, including the American dipper, hellbender salamander, and American alligator.

Early in *Disconnected Rivers*, Wohl states that "a functional river ecosystem is connected to everything around it." This perspective is consistent with what I have learned working in headwater streams and at the Hubbard Brook Experimental Forest in New Hampshire, where there is a long history of exploring connections between stream and terrestrial ecosystems (Likens and Bormann 1974, Likens 2004). It is also, I think, an important alternative to the more traditional focus on the complexity of physical and ecological processes *within* streams and rivers. This traditional in-stream focus has generated a lot of valuable information, but has not provided the understanding needed to address threats stemming from large-scale alteration of stream and river networks and of surrounding landscapes. It is a great sign of progress that Wohl's expansive view of stream and river ecosystems is gaining support, and that we are seeing interest within the scientific community in addressing landscape-level questions related to the protection of these systems (e.g., Fagan 2002, Wiens 2002, Ganio et al. 2005).

The weakness of *Disconnected Rivers* is the lack of a coherent structure that makes clear *why* it is so important for the public, managers, and scientists to recognize the connectedness and continuity of streams and rivers. Too much information is presented without context, both in the text and in figures, and the reader is forced to jump between sections loaded with facts that are not linked to an overarching thesis. Although individual sections of the book are well written and informative, there is little effort to help the reader process this information and draw general conclusions from it. Instead, Wohl repeatedly lapses into

broad and overwrought language to force her larger points. For example, she writes, "The society in which we live reflects immaturity, irresponsibility, and selfishness" (p. 262). This may be true of some elements of society, but an author must present a very convincing case for such a strong statement to avoid coming across as pious and patronizing.

The great strength of Rivers for Life is its clear and thorough review of the economic and political factors that determine how river flows are managed, the ecological objectives that should guide flow management, and the consequences of river regulation under both current and ecologically optimal management regimes.

Reading *Disconnected Rivers*, I felt that the author's deep appreciation of the physical and ecological complexity of rivers was overshadowed by intense frustration at the many wrongs that have been inflicted on rivers since Europeans arrived in North America. Intense frustration may be a logical outcome of the realization that rivers are connected to everything around them, and therefore susceptible to myriad stressors. Unfortunately, this book does not provide readers with enough clear and coherent evidence of the connectedness of rivers to justify the space devoted to broad accusations of human irresponsibility and to the enumeration of threats to river networks.

Focus on the flow

Rivers for Life, by Sandra Postel and Brian Richter (2003), is an excellent book on the ecological impacts of large dams and flow regulation, the strategies for mitigating these impacts, and the legal and political context of river management in the United States and other countries. The first chapter addresses the consequences of flow modification

and resulting ecological degradation for the resources that humans draw from rivers and the species that inhabit rivers, and presents a conceptual model of sustainable flow management. In the second and third chapters, which I found the strongest in the book, the authors outline the evolution of concepts guiding river management in the United States over the last century, the science underlying these concepts, and the methods used in their application. Also in chapter 3, and throughout chapter 4, Postel and Richter combine case studies and policy reviews to show the diversity of ecological and institutional obstacles to the effective management of large rivers, and to introduce innovative approaches to these obstacles. The fifth chapter reviews international perspectives on the costs and benefits of large dams, and the challenges and opportunities associated with transboundary management of rivers. In the final chapter, the authors summarize their case for restoring natural flows to protect large rivers, and present their opinions on the best ways to achieve this goal.

The great strength of *Rivers for Life* is its clear and thorough review of the economic and political factors that determine how river flows are managed, the ecological objectives that should guide flow management, and the consequences of river regulation under both current and ecologically optimal management regimes. The writing is very accessible, the connections among sections within chapters and among chapters are logical, and the information builds on itself to create a strong case for the ecological imperative of restoring natural flows. Although the driving themes of the book relate to ecological implications of flow regulation and flow restoration, I was particularly impressed by the discussions of cultural aspects of river regulation, including the development of a science of regulated rivers, and the complexities of US water law.

In the second chapter, Postel and Richter describe the evolution of the science of regulated rivers, from the rift between basic and applied river science in the 1970s and 1980s to the broad recognition in the 1990s of the importance of

“minimum viable flows” and the recent emphasis on maintaining the full spectrum of flows that approximate the natural regime. This discussion leads into a review of federal and state water policy in the United States, in which the authors address differences in state laws regulating the use of flowing water, highlighting important differences in attitudes toward fresh water within the United States. They also review improvements in these laws by focusing on the tension between persistent economic demands for water allocation and our expanding understanding of the flows required to maintain functional river ecosystems. Postel and Richter successfully illustrate the dynamic nature both of river ecosystems and of the science and policy guiding river management. They show the risks and opportunities that result from our ability to control river flows, reinforcing their points with case studies from rivers in the United States, South Africa, and Australia.

My only criticism of *Rivers for Life* is that the authors do not address the continuity of flowing-water systems, or the implications of this continuity for the restoration of regulated rivers. The book maintains a consistent focus on flow—a variable that has strong effects on river ecosystems, and one that is often possible for humans to regulate directly using the many dams we have built. But flow is only one of many factors that interact to determine the physical and biological attributes of healthy rivers (Ward 1998, Saunders et al. 2002), and many of these factors are strongly dependent on the status of upstream tributaries (Meyer and Wallace 2001) and on linkages between tributaries and surrounding landscapes (Pringle 2001). The fundamental continuity of streams and rivers and the related importance of land–water interactions greatly complicate the restoration of regulated rivers, but acknowledging these issues is critical to promoting the multiscale and multilayered management actions that are needed to maintain healthy rivers.

Megawater

In *Keepers of the Spring*, Fred Pearce (2004) makes vividly clear the politics

and promises that drive large water development projects in both developing and developed nations, the harm that these projects can inflict on humans and natural systems, and the traditional knowledge and innovations that have the greatest potential for meeting future water demands. The first part of the book describes the engineering and “vision” that make huge water development projects possible, and outlines the central role that water management has played in the evolution of human civilizations. The second part presents case studies from around the world that illustrate the political and economic

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conditions leading to water development projects, and the effects of these projects on the environment and on human health. The third section also uses case studies, but to highlight traditional and novel methods of water management that represent the best alternatives to mega-engineering. Pearce concludes with a discussion of the global forces that are likely to influence water management in the near future.

I found this book eye-opening and extremely engaging, largely thanks to Pearce's rich and intimate understanding of the ecological, economic, and political roots of large water development projects. The depth of this understanding is especially apparent in his analyses of cultural and economic forces that drive these projects in water-poor countries, and of the interactions between national interests and international institutions (e.g., UNICEF and the United Nations Environment Programme) that lead to water projects in developing countries. This understanding is exemplified in a chapter on Egypt's High Aswan Dam, built on the Nile River in the 1960s. In concise and fluid writing, Pearce traces the history

of water security concerns in Egyptian culture and politics, and links these concerns to Egypt's current relationships with neighboring countries. In a later chapter, he reveals the connection between natural contamination by arsenic and fluoride of groundwater in India and Bangladesh and a guiding assumption in international aid agencies that water from underground aquifers is inherently safe.

Unlike the authors of the previous books I've discussed, Pearce also shows the human dimensions of the mismanagement of rivers and other freshwater resources. To accomplish this, he has spent time on the ground in regions where large-scale water projects have been completed or are planned, and time with the people whose lives are affected by these projects. The details that emerge from Pearce's interactions with these people and from his descriptions of their living conditions show the basic needs that often underlie large-scale water projects, as well as the unintended, cascading effects of these projects.

A strong sense of despair comes across in Pearce's description of time spent in Karakalpakstan, a semi-independent republic in Central Asia where large Soviet-era dams and water mismanagement have led to the drying of the Aral Sea, which once supported a strong fishing industry, and to poisonous salt concentrations in food grown on irrigated fields. The same impact comes across in his interactions with people in India and Bangladesh suffering from cancerous ulcers and bone malformations due to toxic levels of arsenic and fluoride in well water. These and other sections of *Keepers of the Spring* highlight the tragic fact that areas of the world where effective water management has the greatest potential to improve people's lives are also places where the consequences of mismanagement are the most dire. Later examples of the importance of individual ingenuity and traditional knowledge in meeting water demands provide some counterbalance to these sections. However, it is difficult to see how benefits of these decentralized grassroots initiatives can offset the extent and intensity of harm caused by the megaprojects.

Although it lacks the broad ecological perspective found in *Disconnected Rivers*, and the in-depth description of how regulated flows affect river ecosystems found in *Rivers for Life*, Pearce's book expertly addresses the ecological effects of dam construction, flow diversion, and intensive irrigation, as well as other scientific aspects of freshwater management. There is an excellent chapter on the ecological impact of flow regulation on the approximately 3500-square-kilometer Hadejia-Nguru wetlands in northern Nigeria, and another on the Tehri Dam in the western Himalayas that underscores the tremendous risk of building dams in areas prone to large earthquakes. Considering the diverse audience for which this book is written, I was also impressed by the nuanced discussions of water conservation and the legacy of the green revolution. For example, Pearce points out that water "lost" as a result of inefficient irrigation may, in fact, be important in maintaining underground aquifers, and that the water demands of many "superyielding" crops greatly increase their real cost.

Keepers of the Spring is an exceptional book, and one that deserves to be read by anyone interested in the status and management of the Earth's freshwater systems. It is an especially valuable resource for those of us who live in developed nations, and who may have lost touch with the direct ties between freshwater management and human life that exist in many areas of the world. I will incorporate elements of all three books reviewed here in classes I teach, but I can easily envision building a seminar on national and international freshwater management around *Rivers for Life* and *Keepers of the Spring*.

I recently had lunch with a colleague who has extensive experience conducting research and advising managers on floodplain restoration, protection of Pacific salmon, and optimal flow regimes for large rivers. Most of my experience comes from research on how land use affects biotic communities and ecosystem processes in headwater streams, and from consulting with people who manage

lands composed of small headwater drainages. When the conversation landed on the topic of river restoration, my colleague expressed the strong conviction that the only way to restore rivers successfully was from the bottom up: from the estuaries to the headwaters. I responded with my own strong conviction that the only way to restore rivers was from the top down: from the headwaters to the estuaries. This debate underscores the challenge of developing restoration strategies that address the continuity and connectivity of streams and rivers. The books reviewed here are valuable reminders of the complex relationship between human societies and freshwater resources that frames this and other issues of freshwater management, and the importance of considering the historical roots and unintended consequences of this relationship while working to address these issues.

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