Letters

NOT A PANACEA

The recent article "The Natural Flow Regime," by N. LeRoy Poff et al. (*BioScience* 47: 769–784), presents the case that a thorough scientific understanding of the "natural dynamic character" of river ecosystems is essential for effective management of stream flows, especially where management objectives call for maintaining or restoring ecological integrity. Although we agree that consideration of the natural flow regime will be a necessary component of restoration efforts, we have reservations about prospects for recovering damaged river ecosystems when efforts are founded solely on flow management. The potential for success of flow management strategies will depend on the extent to which target species or communities are limited by other factors, such as contaminants or the presence of nonnative species, that may not be responsive to changes in the flow regime.

Our experience with the Colorado River system has left us cautious about prospects for ecological restoration based solely on manipulation of flows. The natural flow regime of the Colorado River system has been altered on a massive scale by construction and operation of an extensive network of dams and diversions. This alteration has had significant ecological consequences, including a major role in the decline of the native fish community (several native fishes are on the verge of extinction, and others are federally listed). The native fishes are also threatened by introduced non-native fishes (Tyus and Saunders 1996) and contaminants (e.g., selenium). During the same period of time in which water resources were being developed in the Colorado River basin, more than 50 non-native fish species were introduced. Some non-native fishes have become abundant, and through predation or competition, most of the non-natives have been detrimental to the native fish populations.

The threat posed by the non-native fishes is sufficiently severe that it could thwart recovery efforts that depend entirely on restoring or manipulating the flow regime. Manipulation of flows has been proposed as a mechanism for controlling the abundance of non-native fishes in the Colorado River system, but despite the optimistic remarks by Poff et al., there is little evidence to justify the technique. In the article cited by Poff et al., the authors (Minckley and Meffe 1987) were careful to state that their conclusions about controlling non-natives were based on observations made in canyon-bound reaches of small or intermediate-size streams subject to high magnitude floods; their conclusions were not intended for mainstem or alluvial reaches.

In addition, Poff et al. exaggerate unnecessarily in their statement (p. 777) that "virtually the entire native river fish fauna [of the southwestern US] is listed as threatened under the Endangered Species Act (ESA)." Few would argue that the native fish communities are in serious trouble, but the point is sufficiently compelling without exaggeration: 17 of 36 species native to the Colorado River basin are now listed under the ESA (Carlson and Muth 1989). Also, the authors claim (p. 777) that the "last remaining strongholds of the native river fishes are all in dynamic, free-flowing rivers...." In fact, the largest population of the razorback sucker, a species that is part of the big river fish community, is in Lake Mohave, Arizona–Nevada.

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References cited

Carlson CA, Muth RT. 1989. The Colorado River: Lifeline of the American Southwest. Pages 220–239 in Dodge DP, ed. Proceedings of the International Large River Symposium. Ottawa (Canada): Canadian Special Publication of Fisheries and Aquatic Sciences. Publication no. 106.

Minckley WL, Meffe GK. 1987. Differential selection by flooding in stream fish communities of the arid American Southwest. Pages 93–104 in Matthews WJ, Heins DC, eds. Community and Evolutionary Ecology of North American Stream Fishes. Norman (OK): University of Oklahoma Press.

Tyus HM, Saunders III JF. 1996. Nonnative fishes in the Colorado River basin and a strategic plan for their control. Final report to the Colorado River Recovery Implementation Program for Endangered Fish Species in the Upper Colorado Basin. Denver (CO): US Fish and Wildlife Service.

Response:

The point raised by Saunders and Tyus, that ecological restoration of severely altered river ecosystems might not be achievable by flow management alone, irrespective of other limiting factors, is universally appreciated by practicing river ecologists and managers. Indeed, Figure 1 of our article ("The Natural Flow Regime," *BioScience* 47: 769–784) identifies several "other factors" that directly influence ecological integrity, including water quality and biotic interactions. Furthermore, we pointed out that factors such as thermal and sediment regimes must be considered in developing any specific restoration plan for an individual river. The intent of our paper was not to cast the natural flow restoration as a "panacea" for river management, but rather

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as a "cornerstone" (p. 781) that has been overlooked for too long.

We agree with Saunders and Tyus that the proliferation of non-native species in many river systems (not just the Colorado River) is extensive. However, their assertion that there is "little evidence to justify" controlling non-native abundances through flow naturalization in large alluvial rivers misses two important points. First, natural flows have rarely been restored in regulated large rivers—even the important Glen Canyon release we described was a limited effort. Lack of direct experimental evidence is, at best, a weak argument against the potential benefits that re-regulating large rivers may have in restoring native fishes.

A second, more significant missed point is that ample indirect evidence clearly supports our contention that native diversity is likely to benefit from restoring some component(s) of the natural regime—even for large alluvial rivers. For example, in both the flow-regulated Colorado River (Stanford 1994) and the Columbia River (Li et al. 1987), fewer non-native species occur in free-flowing segments, in which habitat and ecosystem conditions are most similar to the pre-impoundment conditions experienced during the evolutionary history of the native species. Restoration of natural flow conditions may then be reasonably expected to benefit native species—indeed, this was one purpose of the controlled Glen Canyon release.

Saunders and Tyus imply that because at least one native species in the Colorado River system (the razorback sucker) has a large population in a reservoir, this big river fish would not benefit from flow naturalization. However, although this species is able to reproduce in the reservoir, it is unable to recruit new individuals into its population, due to the presence of non-native predators (Minckley et al. 1991). Other long-lived species in the Colorado River system and in California also persist for up to several decades as "senescent" populations that cannot recruit and are thus doomed to eventual extinction (see references in Minckley and Meffe 1987). Therefore, active flow management may be needed to facilitate natural recruitment and persistence of big river fishes. For example, in the Green River of the upper Colorado River Basin, restoration of historically high spring flows below the Flaming Gorge Reservoir may increase relatively warm, food-rich channel margin and floodplain habitat that may be critical to the recruitment of juvenile razorback suckers (K. R. Bestgen, Colorado State University, personal communication).

We hope that readers of our article will agree with our concern for managing and restoring rivers toward a natural flow regime and not take away the message that other problems, such as non-native species, can be ignored. Restoring a river's dynamic character to some approximate semblence of its natural state will clearly benefit many native species adapted to such dynamism—and on this basis alone, the natural flow regime deserves consideration as a cornerstone of river management. Moreover, there is strong evidence that under natural flow conditions, non-native species are either reduced in abundance or have diminished negative impacts on native species. This evidence compels us to consider flow restoration as an important adaptive management tool, even in large rivers, in which direct experimental evidence for the efficacy of such intervention may be currently limited.

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References cited

Li HW, Shreck DB, Bond CE, Rexstad E. 1987. Factors influencing changes in fish assemblages of Pacific Northwest streams. Pages 193-202 in Matthews WJ, Heins DC, eds. Community and Evolutionary Ecology of North American Stream Fishes. Norman (OK): University of Oklahoma Press.

Minckley WL, Meffe GK. 1987. Differential selection by flooding in stream fish communities of the arid American Southwest. Pages 93-104 in Matthews WJ, Heins DC, eds. Community and Evolutionary Ecology of North American Stream Fishes. Norman (OK): University of Oklahoma Press.

Minckley WL, Marsh PC, Brooks JE, Johnson JE, Jensen BL. 1991. Management toward recovery of the razorback sucker. Pages 303-357 in Minckley WL, Deacon JE, eds. Battle Against Extinction: Native Fish Management in the American Southwest. Tucson (AZ): University of Arizona Press.

Stanford JA. 1994. Instream flows to assist the recovery of endangered fishes of the Upper Colorado River Basin. Washington (DC): US Department of the Interior, National Biological Survey. Biological Report no. 24.

"EARTH" AS THE METAPHOR FOR "LIFE"

In his article "In Dispraise of Reductionism" (*BioScience* 47: 795–797), Erwin Chargaff rightly criticizes attempts "to explain" and "to understand" the meaning of "life" by appeals to chemistry and physics, although the reductive approach is hard to avoid. Even Erwin Schrodinger placed his faith for the answer to "What Is Life?" in "other laws of physics hitherto unknown," rather than in laws of biology or in principles of ecology.

To a large extent, language is to blame. We think by means of metaphors (Lakoff and Johnson 1980), and the reigning metaphor for "life" is "organism." A brief look at the scientific literature shows that the two words are used interchangeably; no difference is drawn between them. Therefore, when scientists address the "problem of life" they automatically and unquestioningly turn their attention to organisms, especially to simple organisms, asking the explanatory "how" question: "How did this primitive bacterium get put together?"

Two answers are currently popular: the Darwinian and what I will call the Kauffmanian, after one of its chief exponents (Kauffman 1995). The first proposes that complex replicating molecules ("early life") formed by accident in a chemical sea-soup. They were cobbled by random shots-in-the-dark of some cosmic staple-gun (irradiation, lightning, vulcanism), and natural selection did the rest. The second proposes that replicating molecules formed because of matter's self-organizing tendencies in energetic environments. Out of the sea-soup came ever more elaborate dissipative structures, autocatalytic sets and autopoietic systems, fine tuned thereafter by natural selection.

In both explanations, a reductive view of life is forced by the metaphor "organism," because how an organism is organized and how it functions are questions that direct attention to internal mechanisms—to structure, anatomy, physiology. Therefore, the answer to life must lie somewhere within the organism, inside the cell, inside the organelle. By this route, the