A Recipe for River Recovery?

River ecologists are advocating a broader approach to rescuing damaged rivers, betting that restoring the physical processes that shape a river's habitats will bring back ailing fisheries

Look at the Trinity River as it flows through the heavily forested hills of Northern California's Trinity County, and at many spots you will see what appears to be an idyllic natural scene: flashing water coursing between wooded banks. But to the trained eye of a river ecologist, the sight is not so pretty. Those willows and alders along the riverbanks confine the river to a fixed, rectangular channel—a far cry from the shallow and shifting banks typical of a healthy river. And that is only the most outward sign of the transformation that has occurred on the Trinity since a dam completed in 1963 robbed the river of the winter and spring floods that could send as much as 3000 cubic meters of water per second (m^3/s) churning through the channel. For 20 years after the dam was built, the Trinity lived year-round on a comparative trickle, an unvarying 4 m^3/s released from the dam.

Without those annual floodwaters to move sediments down the channel, sweep away encroaching plants, and shift the river's banks, the Trinity's ecology changed dramatically and rapidly. In the mid-1960s biologists with California's Department of Fish and Game already noted vegetation encroaching on the riverbanks. Habitats for frogs, turtles, aquatic insects, and fish that favor the river's warm, shallow edge waters disappeared. Gravel spawning beds used by salmon filled with sand, and the local Hoopa Valley Indian tribe saw a precipitous decline in its traditional salmon fishery.

The Trinity's plight is all too common. Countless rivers and streams in the water-poor West have suffered intense damage from dam projects built in the first half of this century. Fisheries were devastated, and several species of salmon and other commercially important fish hit the endangered list. "The way the dams were built was at best incredibly naïve," says San Francisco–based consulting hydrologist Philip Williams. "[They] were planned ignoring ecologic impacts."

But the Trinity is more than an example of a damaged river. It has become a test case for a new, albeit controversial, approach to river restoration that takes a broader perspective than has been previously taken, focusing not on single fish species but on the whole river system. The approach reflects a growing awareness that habitat modification efforts must take into account all the varied processes that shape an ecosystem (*Science*, 13 September, pp. 1518, 1555, and 1558).

Until recently, restoration efforts on rivers like the Trinity were typically led by fisheries biologists, who generally leaned heavily on a physical habitat simulation model, which goes by the catchy acronym PHABSIM. Developed by the Fish and Wildlife Service in the 1970s, the model focuses on optimizing habitats for a single important species of fish, such as salmon. Now, says Williams, "there is another group of ecologists who see restoring natural processes as a key."

Williams is referring to the natural physical processes that help a river shape its banks and bottom. These processes are best restored, according to river morphologist Luna Leopold of the University of California, Berkeley, by mimicking the seasonal variability in water flow, including occasional torrential floods like the experimental flood released last year on the Colorado River (*Science*, 19 April, p. 344). The effect is to make the rivers smaller versions of what they were before they were dammed. That "doesn't mean you can't use the water," says Leopold—indeed, half or even more of a river's natural flow may be diverted. But the remaining water must be used "to keep the river in some kind of equilibrium which depends on both high and low flows."

A hot political issue

Like all water issues in the parched West, however, this approach is fiercely controversial because higher flows would take water away from agriculture and from slaking the thirst of cities like Los Angeles. And even ecologists are not in total accord on the idea. Proponents of restoring more natural river processes believe, for example, that the approach is not only better for river ecology in general but will also produce the greatest numbers of healthy fish. But they don't yet have the numbers to prove that true, and critics argue that the impact on fisheries is far from certain. "It will make a great river," says Andrew Hamilton, a biologist with the Fish and Wildlife Service. But how much it will improve fish numbers, he says, is "just a wild guess."

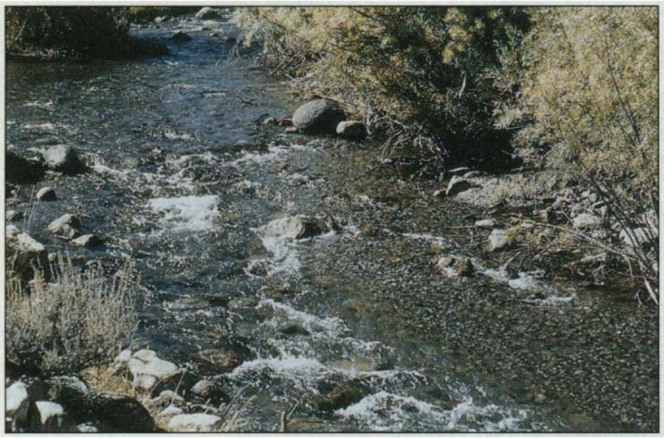
These arguments will be played out publicly over the next year, in two cases. At the end of this month, the Fish and Wildlife Service will release its proposal for restoring the Trinity River, and a similar restoration plan released last February for the streams that feed Mono Lake on the east side of California's Sierra Nevada—which were dried up in 1941 by water diversions to Los Angeles—will undergo public hearings sometime within the next year.

What happens in these cases is being closely watched by river experts concerned with the conflict between water demands and efforts to maintain or restore healthy rivers. "There is a full court press to get all the [restoration] done that we can," says Kirk Rodgers, deputy regional director at the Bureau of Reclamation for the mid-Pacific region, "because many people are visionary enough to see that other [water] demands are picking up. They are trying to re-establish what [habitats] they can and put a protective cloak around them."

In an early effort to provide guidance for trying to improve prospects of river fisheries, in the 1970s the Fish and Wildlife Service developed a system of models for predicting how water-flow changes in a river would influence the capacity of the river to produce fish. At the core of this approach was PHABSIM, which predicts the depths and speeds of water that correspond to different levels of flow in a river and matches them with the known habitat preferences of fish. Water flows can then be adjusted to maximize those preferred habitats.

But many fisheries biologists say that PHABSIM presents a distorted view of what is best for a river, because it focuses too narrowly on the needs of one species of fish, and generally on just one critical life phase. For example, it might focus on ideal conditions for the rearing of juvenile Chinook salmon, which typically prefer "slow, relatively shallow water," says Sam Williamson, a research ecologist with the National Biological Service in Fort Collins, Colorado. If you only take that information into account, he notes, it might lead to a recommendation that a lot of water can be diverted with no harm to the fish. But it would ignore other needs of the salmon, such as for faster, deeper water to bring them food and keep the water temperature cool, and would also disregard the effects of such low flows on the shape of the river channel.

PHOTOS BY G. SMITH



Restoration target. The left photo shows Rush Creek, one of the five streams that feed Mono Lake, at a site above the water-diversion facility, and the right photo shows a reconstructed gravel spawning bed on the lower part of the creek.

Williamson and others maintain that the model is not supposed to be applied that way; a complete analysis should also include factors such as how different water flows would alter the river channels. But many ecologists complain that these more complex aspects tend to get overlooked by agencies and consultants who are seduced by the numbers generated by PHABSIM and who often recommend low water flows as a result. "Whether [PHABSIM] is science or not … boy, it looks great," says Gary Smith, a fisheries biologist with the California Department of Fish and Game.

That was the case, for example, in the late 1970s when the Fish and Wildlife Service applied the analysis to the Trinity River. It recommended that the river's water allotment be roughly doubled to tripled, depending on the wetness of the year. Cecil Andrus, secretary of the interior at the time, implemented that increase, but also called for a 12-year study of the Trinity to determine whether other changes in its management were needed.

PHABSIM falls short

That study began in 1984, but by 1990 Robert Franklin, chief of the water division of the Hoopa Valley Tribe's fisheries department, was unhappy with how it was progressing. He felt the analysis relied too heavily on a narrow PHABSIM approach that would not recommend the variation in flows necessary to restore the natural processes of the river: "The tribe's position is that a healthy river is what you are striving for, and it will produce fish."

Franklin hired Arcata, California–based river-ecology consultants William Trush and Scott McBain to study the processes that create and maintain the river channel, including high flows. The need for these flows, known in the business as channel-maintenance flows, comes from a growing consensus about what is necessary for the health of an alluvial river—a river that has the potential to move its banks and bottom. One key standard, says Trush, is the ability to move the so-called "bed"—the full complement of sediments, from fine sands to boulders—down the river channel. This is essential for many river processes, such as the formation of transient gravel bars that provide river habitats, and maintenance of the gravel beds that fish use for spawning. "If you don't mobilize the bed, the fine particles intrude into the bed, fill up the interstitial areas, remove the habitat for invertebrates, and it destroys the spawning quality," Trush says.

To determine how much the bed needs to move, and how much water it takes to move the larger rocks in the bed, river morphologists study streams that haven't been altered or dammed, mark rocks, and see how often and at what flow levels they move. They have even devised elaborate trapdoor systems in the bottom of one Montana stream to sample rocks and sediments that are moving downriver, says Larry Schmidt of the U.S. Forest Service in Fort Collins. The conclusion from studies carried out over the past few decades: "You have to mobilize the channel bed on the average every other year," says Trush.

Since 1991, floods lasting several days each have been released each year on the Trinity. Because flows on the river must be limited to a maximum of about 170 m^3/s to avoid threatening homes built on the river's banks, the torrent was not sufficient to rip out vegetation that had been growing there for more than 30 years. But prior to the floods the study group had created several experimental sites, removing the invading vegetation with bulldozers and restoring the banks to a more natural shape.

Those physical changes, combined with the experimental flows, produced encouraging results. "The sites where they skimmed off the banks are narrowing on themselves," says Trush. "They are creating a morphology that is typical of alluvial rivers," such as shifting gravel bars in the river channel. Moreover, the researchers could see that fish preferred some of the renewed habitats. Some sites, especially those that had shallow banks, slow water, and gravel and cobble bottoms, had "extremely good use by [salmon] fry," says fisheries biologist Mark Hampton, who worked with the Fish and Wildlife Service on the Trinity project.

A modeling study the team did to analyze the effects of water levels on river temperatures also argued in favor of floods. In the spring, when the young Chinook salmon are migrating to the sea, they are very sensitive to water temperature. A river that doesn't get its normal allotment of snow melt will flow slowly, warming up more than the fish can tolerate. But the temperature model showed that flows of about 55 m^3/s could carry the young fish downstream quickly in a surge of hospitably cold water.

Buoyed by results such as these, the flow study group will recommend in its report, due out on 30 September, that the Trinity's water allotments should be increased. In the driest years, they would be only a little higher than the present allotment, but in wetter years when there is more water available, the annual volume of water coursing down the river would more than double. The majority of the extra water would surge down the river in the spring, when high flows are important not only to keep the temperature cool for migrating fish, but to move sand and gravel downstream and prevent seedlings from germinating and taking hold on the river banks. Those high flows would be punctuated with floods once every year or so to help maintain the river channel.

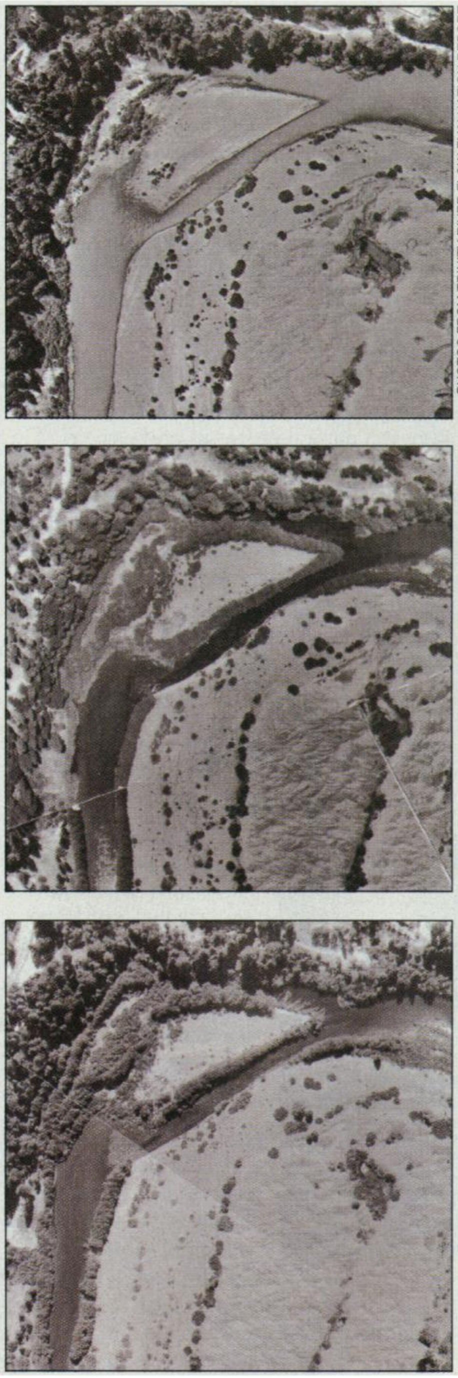
The flow study on the Trinity represents one of the most intensive studies of any U.S. river. "There is certainly a lot of science in the data collected that the recommendation is based on," says Hampton. But while the data suggest that fish will do better in the renewed habitats, it is impossible to quantify the expected improvement in terms of numbers of fish. "The underlying assumption ... is that you have to believe that restoring those natural processes will be good for the fishery."

But before the Trinity recommendations are implemented, the Bureau of Reclamation will take comments from water-user groups who may not be so willing to accept that assumption. "The whole channel-maintenance approach will come under intense scrutiny by water users," predicts Berkeley-based river ecologist Frank Ligon. Diverted Trinity river water travels through several power-generating stations on its way to the Sacramento River, and meeting the flow-study requirements would mean a reduction in power equivalent to what could sustain a community of 100,000 people, says Rodgers of the Bureau of Reclamation: "The power community is very concerned already." Likewise, the potential reduction has raised concern among municipal and agricultural users, says Jason Peltier, manager of the Central Valley Project Water Association, a consortium of water users.

Water users have become more environmentally enlightened, says Peltier, and recognize that to guarantee a stable future water supply they must "address and resolve" fishery problems. But nevertheless they will want to know what their sacrifice will produce in terms of fish. The users can "tell you in dollars and cents how it is going to affect them," says Rodgers, but "you cannot [tell] them what they are going to get in terms of pounds of fish or quantity of fish."

"The biggest challenge for the policy folks is how do you assess this now?" says Serg Birk, a biologist who worked on the Trinity project for the Bureau of Reclamation. "Do you assess it by how many fish return, or by how much habitat you create, or by measuring the parameters that the geomorphologists say indicate a healthy system because it mimics historic flows?" The assessment must consider more than just numbers of fish, says Hampton. "There are many ways to restore a fishery," he says. "You could build a hatchery and restore the fishery. But the Fish and Wildlife Service is in charge of protecting the fish and wildlife resources of the country for the benefit of the public trust. And building a hatchery doesn't necessarily do that."

Even the way that flow management will restore the overall environment requires more study, and the way to do that, says Trush, is through an approach called "adaptive management." This turns the management of a stream or river into an experiment in itself: Hypotheses are formulated, flows are manipulated to answer them, and the management of the river is adjusted accordingly. But to be done properly, adaptive management requires enough water to enable researchers to set up experiments, carry them out, and then alter the program based on their results. And researchers studying the river worry that the amount of water necessary for high-quality adaptive management may not be allotted to the Trinity in the end.



PHOTOS FROM TRINITY RIVER FLOW EVALUATION REPORT

Trees march in. These aerial photos from 1961, 1970, and 1974 *(top to bottom)* show a gravel bar in the predam Trinity that became colonized by trees and shrubs when the dam eliminated floods.

One ideal candidate for adaptive management is another project that Trush has been involved in, the restoration of the five feeder streams for Mono Lake. The lake's volume had been halved and salinity doubled as a result of the water diversions to Los Angeles. Various lawsuits in the 1980s resulted in a requirement that the city reduce by more than 90% the amount of water it takes from those streams until Mono Lake is returned to a healthier level. And in 1990 a Court of Appeals decision added the requirement that the streams be restored to a condition that can maintain fish. It will take at least 20 years for the lake to reach the required level, during which time the increased flows can be used to answer countless questions about what it takes to restore and maintain a stream and its fish population.

While Mono Lake and the Trinity may be two of the most visible cases of the new approach to river restoration, "you will see the same thing on some other rivers in California too," says hydrologist Williams, "as these ideas of ecosystem management permeate the agencies and there is a push to incorporate them into standard operations."

But while channel-maintaining flows may be catching on in California, their future seems less certain in other states. In Colorado, the U.S. Forest Service recently failed to convince a judge to limit future water diversions and guarantee the Forest Service the water necessary for maintenance flows on the South Platte River. Another important case, involving water-rights assignment for the Snake River and all of its tributaries, a water system that covers 80% of the state of Idaho, has yet to be decided. But the Forest Service hopes to learn from its setback in Colorado, as well as from the work going on in California, and present a case for the importance of high flows, channel maintenance, and adaptive management in the Snake River system, says K. Jack Haugrud, an attorney working on the case for the U.S. Department of Justice. "High flows are very important for maintaining stream channels," says Haugrud. "We intend, if we have to, to prove that in court."

It could be a tough sell. "We are in the water-poor portion of the world here," says Williamson of the National Biological Service. "It is easier to say what the minimum flow should be on a stream and divert everything else than it is to spend time trying to figure out what a stream really needs." Adaptive management, says Peltier of the Central Valley Project Water Association, "is a good concept." But it requires not only good science, he adds, but also "risk-taking, which government agencies are totally averse to doing." It will soon be seen whether the public and the water users can be convinced to take a risk on rivers like the Trinity.

–Marcia Barinaga