Great Gravel

New research shows how underground floodplains maintain healthy river "immune systems."

By Jim Robbins

They are beautiful, glistening icons of Montana, filled with life, history, and economic value. But there is far more to mountain rivers than the water churning between their banks

Authors of an important new study published earlier this year examined the essential role of gravel-bed rivers in western mountain ecosystems—the first time an interdisciplinary team has looked at river systems on such a large scale.

"A river doesn't just flow down the channel," says F. Richard Hauer, professor of stream ecology at the University of Montana and the paper's lead author. "It flows over and through the entire floodplain system, from valley wall to valley wall, and supports an extraordinary diversity of life."

Perhaps most surprising of all: "Most of the water in these systems is not in the river; it's in the gravel."

The life that depends on healthy mountain river systems is legion. The recent paper, published in the journal *Science Advances*, brought together researchers from Montana and Canada and from different disciplines, including bear, avian, and ungulate biologists. They were surprised to find that a large number of species rely heavily on the biodiversity generated by river ecosystems, not just fish and other aquatic animals. "These gravel-bed river systems are where the magic happens," Hauer says. "Two-thirds of species spend part of their lives in the floodplain." River floodplains are among the most ecologically important habitats on the continent, Hauer and his colleagues concluded, supporting a hidden wealth of biodiversity.

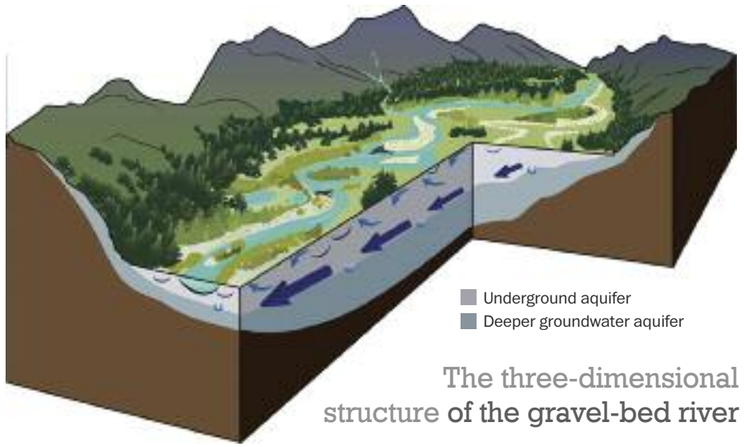
LEFT TO RIGHT: JOHN LAMBING; ED COYLE

MORE THAN MEETS THE EYE
Left: Most water in a river system is not in the channel but in underground gravel that stretches from valley wall to valley wall. Right: The gravel contains microbes that fuel entire river ecosystems.

What most people think of as a "river" is melting snow and groundwater flowing down a channel. But the vast majority of water in a river system is moving far more slowly through the labyrinth of underground cobble, gravel, and sand networks that make up the entire valley bottom, from the base of one mountain range to the other. This subterranean habitat is home to microbes and aquatic insects, such as stoneflies, which are critical to a river's food chain. Water flowing through the matrix of rock and sand filters out organic material and releases nitrogen, phosphorous, and other nutrients that well up through the entire system. These nutrients are then made available to plants and insects on the surface—a jolt of biological adrenaline. This in turn draws birds and beavers, elk and moose. The plant eaters then attract predators.

Before studies of river ecosystems began in the 1970s, scientists thought the "hyporheic" zone—the groundwater of the river system—lay within just a meter or so of the river bottom and banks. Now, after four decades of study, it's clear that the zone takes up most of the river valley.

"I'll never look at a river the same way again," says Michael Proctor, an independent grizzly bear biologist in British Columbia and one of the paper's authors. "It gives my argument to protect river valleys for grizzlies a powerful punch, because I am not just arguing for bears, but for a wide diversity of nature."



The three-dimensional structure of the gravel-bed river

In this cutaway view, the underground "hyporheic" aquifer, characterized by river water flowing through the gravel subsurface, is shown from valley wall to valley wall. The larger blue arrows signify the subsurface waters that develop at the upper end of the floodplain and flow through the underground gravel to discharge into the surface at the lower end of the floodplain as ponds and springs. The smaller arrows near the surface illustrate the water exchange between the surface waters and the upper hyporheic waters in the shallow bed sediments that occurs repeatedly along the length of the floodplain. The smaller U-shaped arrows illustrate the exchange that occurs between the hyporheic zone and deeper groundwaters that are stored for longer periods of time.

Choked to death

That diversity is under siege on several fronts. Human activities such as homebuilding, dam construction, irrigation, and channelization may be slowly choking highly dynamic river systems to death, the paper's authors conclude. Water in many Montana rivers has been diverted for irrigation, essential for agriculture. River courses have been altered by channelization for flood control and by the placement of boulder breakwaters, or riprap, which landowners install to prevent riverbank erosion. These human activities can slow and change a river's flow. Most significantly, they alter the complex interaction between the aboveground course of the river and the unseen currents that wind their way beneath the river valley's broad gravel and cobble bottom. Such human alterations to a river can impair its dynamism and resilience, especially in combination with rising temperatures from climate change and reduced water flows due to increased evaporation and irrigation.

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The cumulative effect of human activities weakens a river's "immune systems," making aquatic organisms more vulnerable to stresses, such as the parasites that overwhelmed mountain whitefish on the Yellowstone in the summer of 2016.

In Montana, a dynamic river is important not just to fish and amphibians, but also to grizzly bears, wolves, and mountain lions descending from the mountains to the floodplain to find prey. Indeed, most of the species in a large river valley spend at least part of their lives in its floodplain.

Then there's the economic value of Montana's moving water. Each year, anglers spend $725 million to fish the state's rivers and streams, according to Montana Fish, Wildlife & Parks.

The new study demonstrates that altering this intricate biological machinery with dams and diversions has far-reaching effects, leading to long-term ecosystem decline. "A river is a huge, huge biodiversity engine with multiple parts," Hauer says. "If you keep taking out parts, pretty soon the engine stops."

River systems are complex. The aboveground river continually jumps channels and makes networks of new ones. Abandoned channels become covered with gravel and transform into important habitat for stoneflies and other insects that feed fish. Water flowing through the gravel beneath

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LIFE FLOWING FROM RIVER GRAVEL Scientists are now finding that the waters flowing beneath river floodplains support an enormous range of wildlife, fish, and other creatures. Clockwise from top left: a giant salmonfly consuming aquatic plants; a westslope cutthroat trout resting on a shallow river bottom; a white-tail doe grazing on river vegetation; grizzlies feeding on an elk carcass. Scientists say that nutrients in the floodplain fuel all this life and more.

CLOCKWISE FROM UPPER LEFT: E. HARRINGTON, EH ILLUSTRATION; VIKTOR KRBOVSKY/ENGBRETSON UNDERWATER PHOTOGRAPHY; LON E. LAUBER; DONALD M. JONES; TONY BYNUM

the valley floor also surfaces in countless places along the floodplain, creating a constantly changing assortment of ponds, seeps, springs, and other important habitat.

Interaction between water in the river and groundwater is fundamental to the river ecosystem. During winter, cold water is stored in the rock and gravel, surfacing in summer to moderate warm temperatures. Pools of warmer water in winter and cool water in summer create refuges for fish and other species.

This mix of water plays a role in preventing disease, which is part of the story of last summer's parasite proliferation on the Yellowstone River. As water is withdrawn for irrigation, and structures such as riprap are installed, the mixing between groundwater and river water is reduced. That means less water is stored in gravel to cool the river in summer and warm the river in winter. The result? A wide range of problems, Hauer says. "[Fish] pool in warmer water and are stressed." Their metabolism increases in warmer water, "and they are not able to eat enough food and are not healthy. That makes them really vulnerable to disease." Warmer water may favor increased populations of parasites, while crowding in the cool water that remains may bring fish into contact with more parasites. That's the "perfect storm" of unfavorable conditions that state fisheries biologists say led to the whitefish die-off last summer.

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Meanwhile, invasive zebra and quagga mussels—a growing problem in the western United States that upsets the ecology of freshwater ecosystems—also favor warmer water. The degradation of river ecosystems may help them thrive, research shows.

All these harmful effects—combined with reduced water flows, longer summers, and warmer water and air temperatures—weaken the resilience of gravel-bed rivers, Hauer says.

From above

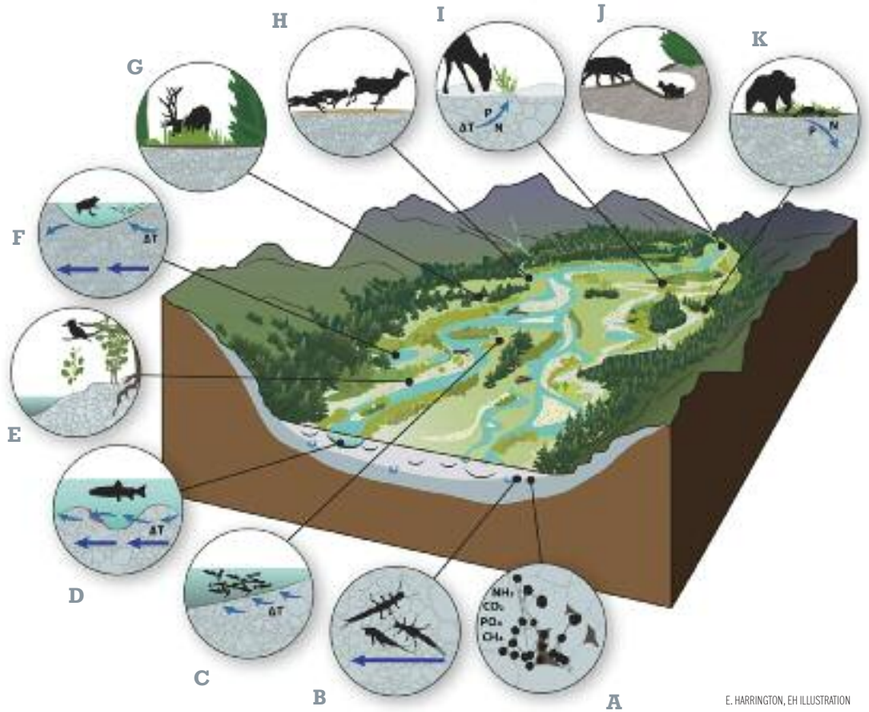
On a recent flight over the Bitterroot River south of Missoula, Hauer pointed out the floodplain. While the river below flowed down a main channel, it was easy to see from the air that, over centuries, the Bitterroot had frequently jumped its bounds to create a network of new channels.

The old channels were covered with gravel, an important habitat for aquatic insects that feed fish. Everywhere in the valley, water that flowed underground through the gravel had surfaced to create a diverse mix of springs and ponds.

Hauer also pointed out several places where people have sought to tame the river's unruly habits with levees and riprap in order to keep floodwaters off land so they can plant crops or build houses. "There's no renewal, the river can't move gravel around and create new mosaics of habitat," he said. "Nutrients are not dispersed. Everything gets locked in place and starts getting old and declines."

The environmental damage is hidden—at first. Channels feeding the underground habitats are sealed off as the river is confined. Then the populations of species that depend on the hidden flows, including trout and other fish, begin to falter.

The implications of this new research are enormous—and could make the conservation of rivers more difficult because it involves human activity on a much broader scale. Scientists say that if we continue to take bits and pieces out of these ecosystems, rivers such as the Bitterroot and Yellowstone will continue to decline, especially as the effects of warming temperatures mount. People don't like to hear that what they are doing is harming a river, Hauer says. But he maintains that society needs to know how its activities are altering the natural world if it hopes to fix ecological problems that affect outdoor recreation and tourism industries.



E. HARRINGTON, EH ILLUSTRATION

Cycles of life in a gravel-bed river floodplain

This illustration shows the complexity of floodplain habitat, the interactions among organisms, and the importance of gravel-bed river floodplains within mountain landscapes. (A) Microbes in the spaces between gravel particles process organic matter. (B) Crustaceans and insects inhabit the gravels of the floodplain. (C) Upwelling underground waters moderate the temperature of surface habitats. (D) Fish spawn in floodplain gravels. (E) Riparian birds prey on small fish. (F) Amphibians spawn in floodplain ponds and backwaters. (G) Ungulates consume floodplain vegetation. (H) Wolves prey on ungulates. (I) Vegetation emerges in early spring. (J) Wolves den along floodplain banks. (K) Carcasses left by grizzly bears and other carnivores decompose and enrich the soil with nitrogen and other nutrients.

THE NEED TO MEANDER **Above: When spring floods reconfigure river channels, old channels become ponds for waterfowl and furbearers, or fill in with gravel that creates important habitat for aquatic insects that feed fish. Below: When landowners try to tame river movement with riprap, channels feeding underground habitats are sealed off. River movement stops, and with it the natural flow of nutrients and water throughout the floodplain.**

CLOCKWISE FROM LOWER LEFT: E. HARRINGTON, EH ILLUSTRATION; CRAIG & LIZ LARCOM; REBECCA STUMPF