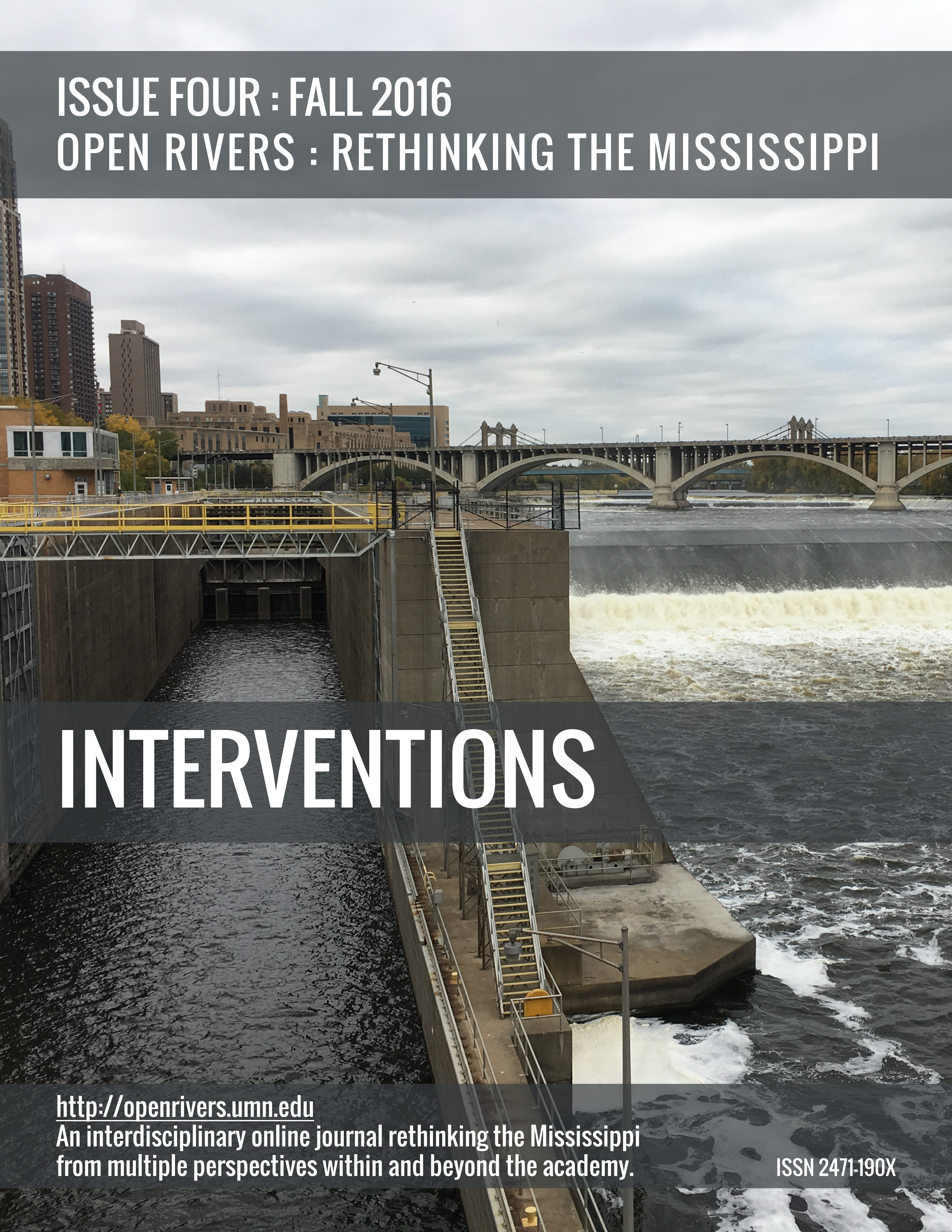

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The cover image is of St. Anthony Falls Lock, closed in June 2015. Image courtesy River Life, University of Minnesota.

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FEATURE

WHAT DO YOU SEE WHEN YOU LOOK AT A RIVER?

By Jessica Kozarek

The Mississippi River in Minneapolis was the focus of a one-year study during 2015-16 to assess the current ecological condition of the river at the time of a major management event, the closure of the Upper St. Anthony Falls Lock (see Mazack, this issue).[1] From the compiled physical, chemical, and biological data, a baseline dataset was developed. Among other findings, the

Sauk River, upstream of the confluence with the Mississippi River at Sauk Rapids, MN. Image by Jessica Kozarek.

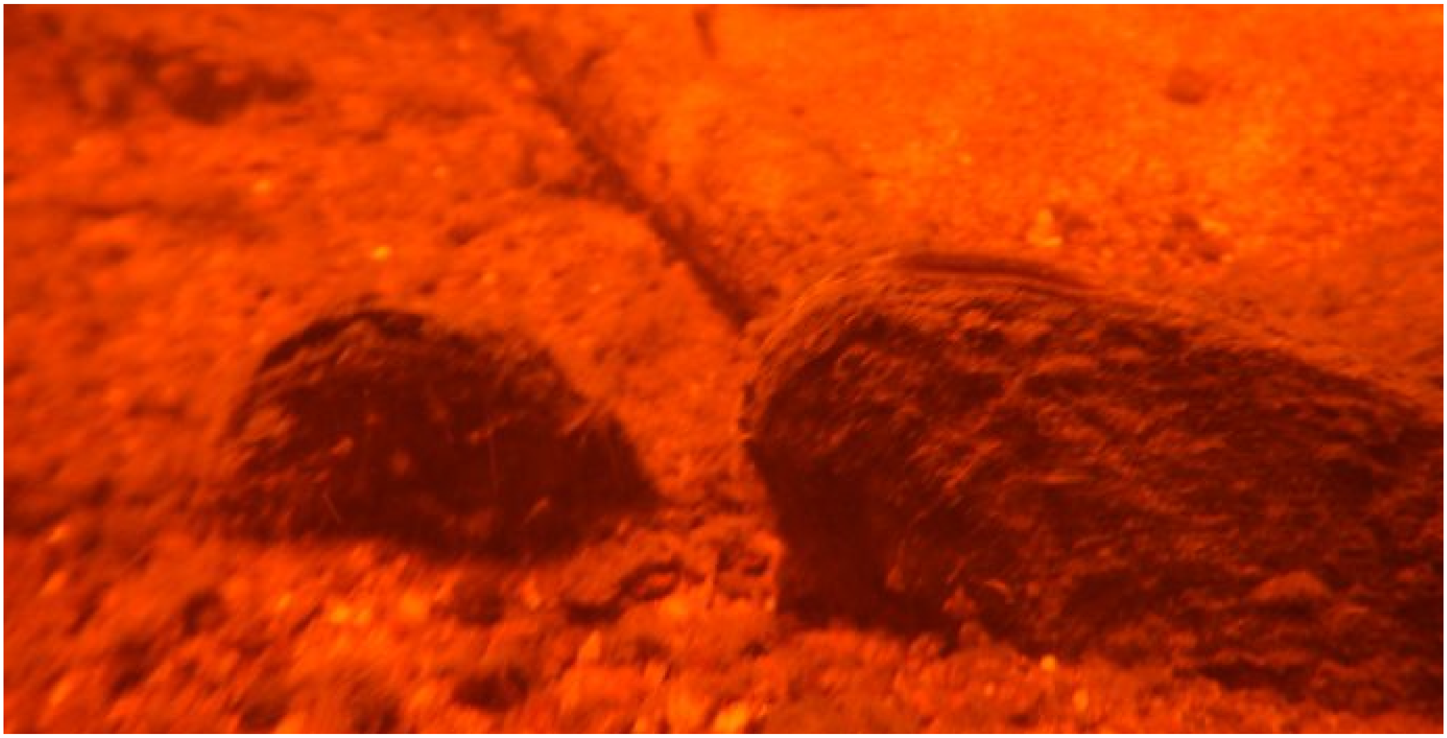
study determined that mussels are a significant component of the river's ecosystem. This article discusses mussels and mussel monitoring in more detail.

So, what do you see when you look at a river?

You might see physical characteristics of the water itself such as whirls from turbulence, waves, or water color and clarity. You might notice vegetation or birds and wildlife within the river. You might see large-scale river engineering projects: locks and dams, flood protection, bridges, or bank stabilization. All that you see and much that you likely can't see together compose the building blocks for an underwater ecosystem. These building blocks are all of the physical, chemical and biological conditions of the river that make it more or less livable for its underwater inhabitants. Physical habitat is the living space of aquatic biota represented by water currents and riverbed material. Physical river habitat is dynamic in space and time as water flow and sediment sources vary with weather patterns and land use practices. Chemical parameters of a river environment include: dissolved oxygen, temperature, nutrients, and pollutants. River water chemistry changes with season, rainfall, and land use practices. Biological parameters of a river habitat include: fish, aquatic wildlife and vegetation, macroinvertebrates (insect larvae, mussels), and microorganisms such as bacteria or algae. Together the physical and chemical environment with the biological community makes up the river ecosystem. By definition, a system is comprised of interconnected components or processes that make up a whole, and the physical, chemical, and biological processes within a river ecosystem are strongly interconnected.

Ecosystem Engineers

The interactions between the physical, chemical, and biological components of a river ecosystem are exemplified by those organisms that directly influence their physical habitat (which in turn affects the chemical and biological processes of the ecosystem). The concept of ecosystem engineering emerged in ecological literature in the 1990s (see review by Wright and Jones 2006). This concept generally refers to the modification of the physical features of ecosystems by a single species or collection of similar species. Human beings are the ultimate examples of ecosystem engineers, altering the physical habitat of rivers and landscapes to suit our needs by building dams, roads, cities, etc. that have cascading effects on the ecosystem in which we live. In the animal kingdom, one of the most visible ecosystem engineering species is the beaver whose dams extensively alter riverine habitat with dramatic effects on aquatic community structure and ecosystem functioning. Other examples of ecosystem engineers include elephants, gophers, and earthworms, all species that alter their physical surroundings. Even vegetation can be considered an ecosystem engineer under certain conditions, as it can significantly modify river flow and sediment characteristics altering the shape and form of a river. Less visible ecosystem engineering organisms that can have significant impacts on the physical structure of riverbed



Freshwater mussels in a river bed. Image by Jessica Kozarek.

Freshwater mussels in a mussel bed.
Source: Mike Davis, Minnesota Department of Natural Resources.

habitat are freshwater mussels. These organisms tend to aggregate in large groups called mussel beds. Mussel beds stabilize sediment and create habitat for aquatic insects, algae, and fish. Note the significant differences between the concept of ecosystem engineering—a community of organisms working together to engineer their habitat—and our human concept of engineering, namely intent. Beavers likely do intend to alter their physical habitat, but it could be argued that mussels' impact on riverbed habitat, while great, was not the intent of the mussels.

See video How Beavers Build Dams by PBS.

I will note at this point that I'm not an ecologist, nor am I a malacologist (a scientist who studies mollusks), and that my perspective on rivers is that of an engineer. I conduct research at St. Anthony Falls Laboratory at the University of Minnesota in a facility devoted to the study of the interactions between stream and river management and stream ecosystem response. This laboratory, dubbed the Outdoor StreamLab (OSL), is an experimental stream and floodplain designed to conduct experiments on a stream ecosystem such as the response of streambed composition, stream morphology, nutrient dynamics and/or biotic community to changes in water and sediment supply or engineering channel designs. Experiments conducted in the OSL during summer 2016 were focused on the feedbacks between mussels and channel morphology or how mussels respond to changing habitat and the impact of mussel presences on habitat in a changing environment.

The Outdoor StreamLab at St. Anthony Falls Laboratory at the University of Minnesota. Image by Jessica Kozarek.

Freshwater Mussels

Mussels are incredibly fascinating creatures that deserve some investigation. I've had the opportunity to learn about mussels from local experts in state and federal government agencies and from my colleagues in academia, who can speak much more accurately to mussel biology than I can, but I will enumerate some key points that make mussels worth thinking about. Mussels are much more than living rocks (although this is what they most resemble); mussel shells come in a wide variety of shapes, sizes, and surface textures. Adult mussel shell length ranges from 1 to 10 inches for different species (for a detailed discussion, see Haag 2012). With common names like "warty back," 'threeridge," "heelsplitter," or "pocketbook," you can imagine the shell sculpture for each of these species with bumps, ridges, wings, or smooth shells. Mussel shell morphology likely evolved to balance out the ability to maintain position without being scoured or dislodged, or to burrow (after dislodging or to avoid predation). Different morphology allows mussels to remain in riverbeds under different conditions. For example, a smooth-shelled mussel may be able to burrow faster, while a heavy, thick-shelled mussel with ridges or shell sculpture may be able to hold position in faster currents. Unfortunately, as mussels live on the bottoms of rivers, it is difficult to watch mussels during high flows, so it's hard to say what they actually do.

Freshwater mussels are abundant and diverse, but also highly imperiled. North America is home to approximately 300 species of mussels (Haag 2012); however, approximately 70 percent of these species are extinct, endangered, or otherwise of special concern. Mussel population decline cannot be attributed to a single factor, but rather a combination of often interacting factors from land use change (e.g., water quality degradation, habitat loss, altered streamflow, and sedimentation), direct channel modification (e.g., dam building), host fish availability (more on this later), and invasive species impacts (e.g., predation and zebra mussel infestation). Because mussels are long lived (some species can live 50 + years), relatively sedentary, and have a complicated life cycle that requires suitable host fish populations, they are often used as indicators of river ecosystem wellbeing. A kind of "canary in the coalmine" organism, mussel response to environmental conditions can signify an early warning for a degraded ecosystem. In fact, instrumented

The author holding a mussel collected from the Le Sueur River in Minnesota. Image used with permission from Amy Hansen.

mussels are being used as biomonitors for water quality. Mussels are filter feeders, and they have the ability to close their shells for a period of time when a contaminant is present. By monitoring mussel gape (i.e., the rate at which they open and close their shells), water resource managers can tell, for example, if all mussels close up quickly, that there is potentially harmful contamination.

Unlike fish, freshwater mussels are relatively sedentary and therefore subject to local environmental conditions. Mussels do have one foot, which allows them to anchor into sediment or crawl along slowly (generally inches to feet a day, at most). Unlike oysters or clams, freshwater mussels have a unique life cycle that depends on a parasitic relationship with a host fish. It is this relationship that allows mussels to spread throughout a river network. Female mussels release mussel larvae (called glochidia), which must attach to the gills of a suitable host where they will grow and develop for several weeks before dropping off of the fish as juvenile mussels. Many mussel species have evolved intricate methods to attract the appropriate fish host to ensure successful attachment of glochidia. These methods range from displaying elaborate lures that mimic fish, to developing packages of glochidia that resemble fish food, to physically capturing the unsuspecting fish host long enough

Diversity of mussel shell shapes and sizes in the Snake River, Minnesota. Image by Jessica Kozarek.

This illustration is from the booklet, "A Pocket Guide to Kansas Freshwater Mussels." It is reproduced with permission from the artist, Karen Couch.

to infest the fish with glochidia. These adaptations are next to impossible to observe in the wild without a snorkel, scuba gear, and/or lots of time and the expertise on when and where to look, but the curious can check out the array of videos online. As they grow, mussels can keep a record of the water chemistry and environmental conditions in their shells. Like trees, mussels develop rings as they grow. The size of each grow ring can show the mussels' growth, and a record of the river chemistry can be captured in the calcium carbonate that makes up the shell.

See videos of mussel lures at the Freshwater Mollusk Conservation Society.

Value of Freshwater Mussels

Descriptions of freshwater mussel diversity and abundance in the large rivers of the central U.S. prior to the 1900s evoked images of dense mussel beds hundreds of feet long and up to two or three feet thick in some areas (Haag 2012; Anfinson 2003). These beds provided the basis of a booming pearl button industry centered in Muscatine, Iowa in the late 1800s to early 1900s. Clammers dragged the Mississippi riverbed pulling up tens of thousands of tons of shells. In the same

Clammers standing atop a mound of mussels killed to make mother-of-pearl buttons. Source: US Fish and Wildlife Service, circa 1911.

time period, fortune seekers were on the hunt for elusive and valuable freshwater pearls. By the early 1900s, mussel beds had been depleted by the massive harvesting efforts and water quality was degrading due to growing human populations. Water pollution from agriculture and sewage made mussel population rejuvenation unlikely, and the button industry died out.

The New York Times published an article in 1902 about the end of the pearl mussel boom.

Modern wastewater treatment following the Clean Water Act of 1972 has greatly improved the water quality in our rivers, to the point that some mussel populations are beginning to recover. Today, freshwater mussels maintain a market as seed material for the cultured pearl industry but are illegal to collect in many states due to their threatened status. The non-market value of freshwater mussels today is more difficult to quantify, although they provide important ecosystem services. As mentioned above, the physical presence of a mussel bed can have a significant influence on riverbed habitat. But mussels influence more than just physical habitat. Mussels are filter feeders, passing gallons of water through a single mussel in a day, removing suspended material from the water column. In large enough numbers, mussels can greatly improve the water clarity. The unused nutrients and organic material that mussels filter out of the water while feeding are deposited in the riverbed stimulating the food web at the river bottom through algal growth and macroinvertebrate production. These processes can cascade up the food chain, ultimately providing more food for fish.

River Ecosystem Management in a Dynamic Environment

Freshwater mussel conservation efforts have shown some promise in rivers where water quality and physical habitat will support mussel populations; however, threats to freshwater mussels and causes for declining populations remain difficult to pin down, likely due, in part, to the interactions between many environmental stressors. Hansen and others published a modeling study in 2016 that provides an example of these interacting stressors in the heavily agricultural landscape in the Minnesota River basin. Land in this watershed is primarily used for row-crop agriculture (converted from a prairie-wetland system). Like much of the Midwest, extensive drainage practices (tile drains and ditches) and crop conversion compounded with changing precipitation patterns and earlier snowmelt have led to increased peak streamflows and suspended sediment concentrations. In turn, suspended sediment can shade or absorb the light and reduce the availability of algae, mussel's primary food. This model indicated that chronic exposure over many years to increased suspended sediment concentrations, combined with food limitation, were the primary factors controlling freshwater mussel population density in the watersheds which they examined. Other environmental stressors, such as pollutants or unstable habitat, may be more critical in river reaches in cities, for example.

I have used freshwater mussels as an example of how one component of a river ecosystem changes and is changed by its environment. This example illustrates that the interactions, feedbacks, and thresholds between components of a river ecosystem can be intertwined and should all be considered when maintaining, restoring, or otherwise managing a river to support life. Other less obvious, but non-structural components of river ecosystems can also drastically alter river ecosystems (see review by Corenblit et al. 2011). For example, feedbacks between hydrology, biogeochemistry (nutrient cycling), sediment transport, and vegetation growth can control river dimensions (width, depth, slope, etc.). As river management trends more toward restoration (see Open Rivers Issue 2) incorporating more environmental goals, understanding the interactions between the physical, chemical, and biological processes in a river becomes critical to successful management. And as the river adjusts to the lock closure and future river management, mussels will serve as indicators of the changes occurring in the river ecosystem.

For more information about freshwater mussels, see:

- http://dnr.state.mn.us/mussels/index.html
- https://www.fws.gov/midwest/mussel/index.html
- http://molluskconservation.org/MC_Ftpage.html

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Footnotes

[1] Funding for this project was provided by the Minnesota Environment and Natural Resources Trust Fund as recommended by the Legislative-Citizen Commission on Minnesota Resources (LCCMR). Funding was awarded to the Minneapolis Riverfront Partnerships and work was completed in partnership with the Mississippi Watershed Management Organization, the Minnesota Department of Natural Resources, and the University of Minnesota's St. Anthony Falls Laboratory and River Life Program.

[2] Funding for this project, "Conserving Minnesota's Native Freshwater Mussells," was provided by the Minnesota Environment and Natural Resources Trust Fund as recommended by the Legislative-Citizen Commission on Minnesota Resources (LCCMR).

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About the Author

Jess Kozarek leads ecogeomorphic research in the Outdoor StreamLab at St. Anthony Falls Laboratory. Jess' research links stream hydraulics to biological processes to develop guidance for stream and river management to protect and restore aquatic ecosystems.