USDA United States Department of Agriculture
Forest Service

PNW Pacific Northwest Research Station

Science FINDINGS

issue two hundred twenty-eight / june 2020

INSIDE

"Science affects the way we think together."
Lewis Thomas

Shading Out Climate Change: Planting Streamside Forests to Keep Salmon Cool

Steve Wondzell

Middle Fork John Day River, Oregon. Along many rivers thoughout the Western United States, there is ample opportunity to replant streamside vegetation that could help cool the water and benefit trout and salmon.

"The practical importance of the preservation of our forests is augmented by their relations to climate, soil, and streams."
—John Muir

Salmon are incredibly hardy creatures. One need look only at their complex and daunting lifecycle to gain an appreciation of their resilience: their long, hazardous swim from stream to ocean—a journey that can be hundreds of miles; their metamorphosis into saltwater creatures that spend their adult lives in the open sea; then their arduous return journey to the stream of their birth to mate and deposit eggs in streambed gravel, dying before the next generation has hatched.

But there are limits to what these fish can tolerate. Although salmon can survive in a range of conditions, water temperatures above their tolerance limits can produce changes in their growth and development, their migratory patterns, their ability to spawn, and the survival of their eggs. In extreme cases, it can result in direct mortality.

A 2002 report by the National Oceanic and Atmospheric Administration (NOAA) stated that the optimum migration temperature for Chinook salmon is between 49 and 57 °F. At 68 °F, they won't migrate upstream at all.

And that's just for migration. The same report states that the optimal temperature for spawning is considerably below the migration temperature, and lower still for the survival of eggs and young fry.

As a result, warmer water resulting from climate change poses a threat to salmon survival.

IN SUMMARY

Climate change poses a clear danger to salmon and steelhead in the Columbia River basin. Rising water temperatures increasingly limit their ability to migrate, spawn, and successfully produce the next generation of fish.

Steve Wondzell, a research ecologist with the USDA Forest Service's Pacific Northwest Research Station, conducted a study on the upper Middle Fork of eastern Oregon's John Day River. By using computer modeling, he and colleagues found that adding shade was the single most effective way to cool the water and preserve habitat for salmon into the future. With enough added shade, they found that future water temperature in the river could be cooler than today, even as air temperatures warm.

Adding sufficient shade involves strategically planting streamside vegetation that will grow tall enough to shield long sections of the river from sunlight. The Forest Service and other federal agencies, the state of Oregon, and the Confederated Tribes of Warm Springs are leading an effort to do just this. They are also working to reconfigure sections of the river that were artificially straightened in the past. Wondzell's research confirms the importance of coupling riparian planting with those efforts and is helping the different parties involved direct their efforts in a more strategic way.

Steve Wondzell, a research ecologist with the USDA Forest Service Pacific Northwest Research Station, says maximum water temperatures in many streams throughout the Columbia River basin already approach—and occasionally exceed—the lethal thresholds for salmon and trout. These are streams that the fish have been using for centuries.

And it's likely to get worse. Wondzell says that climate change will cause stream temperatures to increase in the future, both from increased air temperature and as changes in precipitation patterns result in lower summer and fall streamflows.

The question is what to do about it. Efforts are underway to restore stream and riparian habitat in many streams where populations of salmon are much smaller today than they were historically. But climate change raises serious questions about the long-term outcomes of these restoration projects. Predicted warming could make many of these streams and rivers uninhabitable for salmon and trout in the next few decades.

The stakes are high. Wondzell says that restoration projects within the Columbia River basin constitute one of the single most expensive recovery efforts ever undertaken within the United States, costing several billion dollars.The long-term outcomes of these projects depend on river temperatures remaining cool enough for salmon.

The most hopeful answer, he found, is to increase the amount of shade on these threatened streams.

KEY FINDINGS

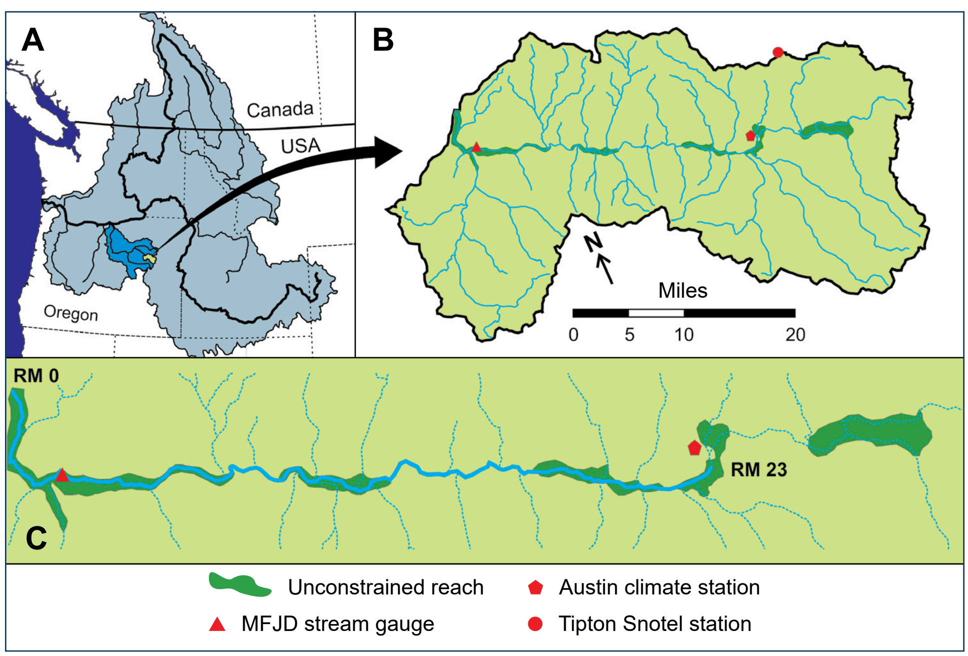
- Stream temperatures are far more sensitive to changes in shade than to changes in either air temperature or stream discharge.
- Restoring riparian forests along streams where shade is currently lacking could result in future stream temperatures that are colder than they are today, even under a warmer climate with substantially lower late-summer streamflow.
- Restoring complex meandering channels in valleys where streams have previously been straightened and channelized can create more habitat for fish. It lengthens the channel and slows the water; however, it can increase the stream's exposure to sunlight. This may potentially exacerbate stream temperature problems if the restoration does not include riparian plantings to provide shade.
- Many stream segments throughout the Western United States have been altered by humans, resulting in less stream shade. This means that today there is great potential to restore shade in many of those areas.

Cool in the Shade

Focusing on a 23-mile section of the upper Middle Fork of the John Day River in eastern Oregon, Wondzell and his colleagues used computer modeling to examine how stream temperatures would change in response to changes in air temperature, stream discharge, and the amount of shade provided by riparian forests. They found that shade was the single biggest factor in determining future maximum stream temperatures. By comparison, air temperature and stream discharge had much smaller influences on the temperature of the water.

"The effect of restoring riparian forests on streams where shade is currently lacking could be so large that future stream temperatures could be colder than today, even under a warmer climate with substantially lower late-summer streamflow," he says.

The John Day study area is one of 14 intensively monitored watersheds in the Pacific Northwest. These watersheds are managed by multiple agencies, and all have restoration projects underway. The intensively monitored watershed program gathers information about what works when it comes to restoring salmon and steelhead populations so that these practices can be applied elsewhere.



The (A) upper Middle Fork John Day (MFJD) catchment (light green) studied in stream temperature simulations. The site is in the John Day catchment (blue), which is part of the Columbia-Snake River catchments (gray) of northwestern United States and southwestern Canada. Inset (B) shows the upper MFJD catchment and (C) shows the study segment with unconstrained valley reaches converted to meadows.

Purpose of PNW Science Findings

To provide scientific information to people who make and influence decisions about managing land.

PNW Science Findings is published monthly by:

Pacific Northwest Research Station
USDA Forest Service
P.O. Box 3890
Portland, Oregon 97208

Send new subscription and change of address information to:

SM.FS.pnw_pnwpubs@usda.gov

Rhonda Mazza, editor; rhonda.mazza@usda.gov

Jason Blake, layout; jason.p.blake@usda.gov

To find Science Findings online, visit
https://www.fs.usda.gov/pnw/
and click on **Publications**.

Become a digital subscriber here:
https://www.fs.usda.gov/pnw/publications/subscriptions.shtml

USDA United States Department of Agriculture

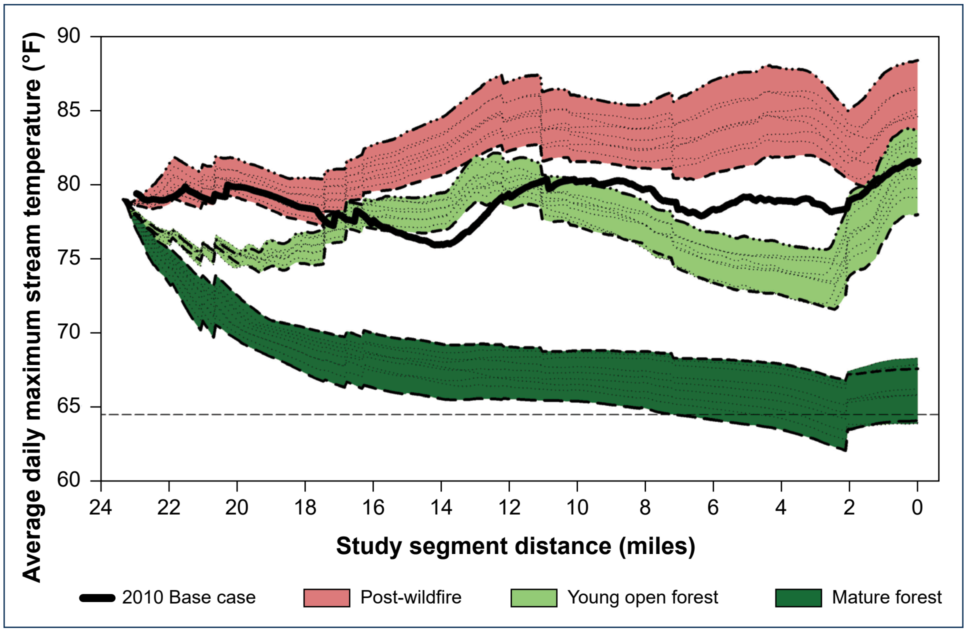
Forest Service

The upper Middle Fork of the John Day River was designated as an intensively monitored watershed in 2008, funded by NOAA and executed through the Pacific States Marine Fisheries Commission and the Oregon Watershed Enhancement Board. As restoration projects are implemented, detailed monitoring follows to evaluate their outcomes. The monitoring involves numerous groups and agencies, including the Confederated Tribes of Warm Springs and the Oregon Department of Fish and Wildlife.

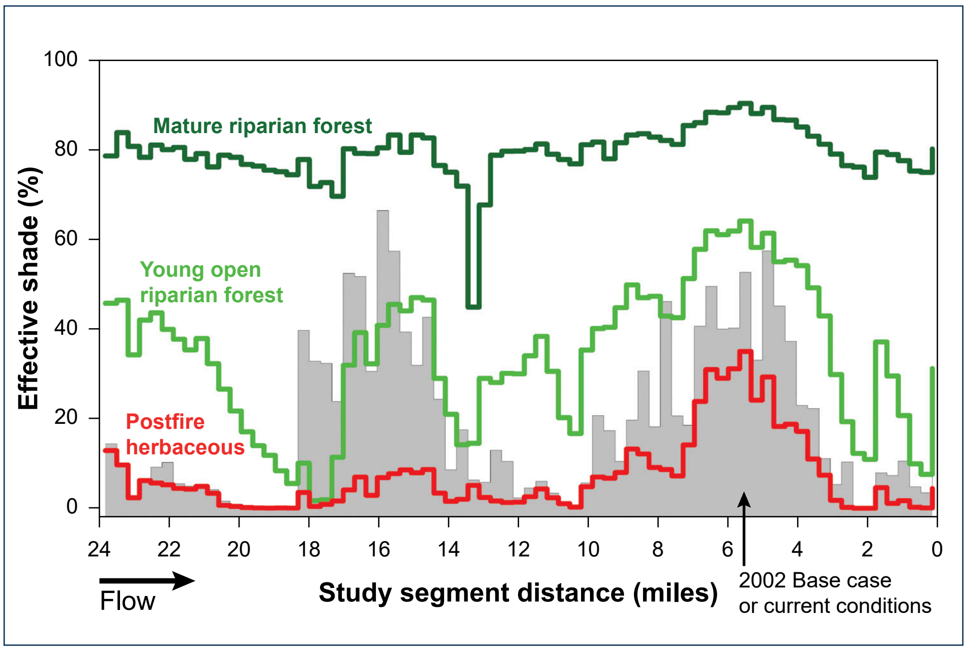
Like much of the Intermountain West, the John Day watershed has been altered by beaver trapping, logging, grazing, and fire suppression over the past century and a half. As a result, fish habitat has been compromised. The upper Middle Fork's steelhead are part of a population listed as threatened under the Endangered Species Act, and spring Chinook populations in the watershed have been declining as well. Scientists found that temperature is the biggest limiting factor for fish recovery in the watershed.

Wondzell's career has centered on researching the ways in which aquatic and riparian habitats are affected by the interactions of hydrological, geomorphological, and ecological processes, and how those processes are also affected by land-use practices. He was intrigued by the restoration efforts and wondered how they might fare in the future, given the expected impacts of climate change. Around the same time, the Forest Service and U.S. Geological Survey jointly set aside money for research into climate change effects on aquatic ecosystems, and Wondzell used that opportunity to begin this study. Wondzell and his long-time collaborator, Roy Haggerty, then a professor at Oregon State University, recruited Mousa Diabat, who undertook the project for his graduate research.

Wondzell and his colleagues looked at realistic future climate scenarios and took into account restoration treatments that are planned or already implemented. Through computer modeling, they were able to project likely future stream temperatures.



Simulated 7-day average daily maximum stream temperatures over the length of the study segment along the Middle Fork John Day River. Simulation results are grouped for three riparian vegetation scenarios: post-wildfire, young open forest, and mature forest. Adapted from Wondzell et al. 2019.



Effective stream shade simulated for July 14 over the length of the study segment for four riparian vegetation scenarios: mature forest, young open riparian forest, postfire, and current conditions. From Wondzell et al. 2019.

Simulating a Shaded Future

The team first examined the potential differences between warmer nights versus hotter days. Some climate change projections suggest that future changes in average air temperature will result more from warmer temperatures at night than from hotter temperatures during the day. The researchers found that the timing of air temperature changes does have an influence on stream temperature changes, but these changes were so small that they could be ignored in their subsequent analyses.

The researchers then examined likely future outcomes. They developed 36 alternative future scenarios to explore how changes in air temperature, stream discharge, and shade affected stream temperatures. Scenarios for changes in air temperature were based on downscaled projections from broad-scale climate models; scenarios for changes in discharge were based on observed interannual variability in streamflows. Shade scenarios were based on potential streamside vegetation structure—contrasting current conditions with mature conifer forests and with conditions after wildfire effects where shade was entirely lacking. The stream temperature simulations demonstrated that shade from riparian vegetation was the single biggest determinant of future stream temperatures. In contrast, when projecting future conditions, modeling showed that changes in air temperature or stream discharge had relatively little influence on stream temperatures.

In one model simulation, forests grew along the entire 23-mile section of the river. As the vegetation got taller, the water temperatures got colder. When the simulated, mature forest was 98 feet tall, the resulting shade reduced midday maximum temperatures on the water by roughly 12 to 16 °F and nighttime temperatures by as much as 5 °F.

The change was remarkable, but is planting that many trees an achievable goal?

"It's possible," Wondzell says. "The height of the trees and the amount of canopy is realistic, but it's unlikely that the entire length of the study site would ever be uniformly forested—given the effects of wildfires and other natural disturbances, along with differences in land ownership and long-term management objectives."

The Confederated Tribes of Warm Springs is partnering with the Forest Service, Oregon Watershed Enhancement Board, and other agencies to work toward a shadier future for the John Day.

To maximize the effectiveness of streamside forests, Wondzell says that planting efforts should be coordinated with other efforts to restore instream habitat such as adding large wood to streams, which creates pools and more complex habitat for fish. And, of course, to be successful, the newly planted saplings need to reach maturity so that the riparian forest can be self-sustaining. Factors that might hinder this include summer drought, competition with herbaceous vegetation, browsing by deer and elk, grazing by domestic livestock, and even beaver activity.

A report by managers of the Middle Fork John Day study area stated that during the last 10 years of monitoring, only ponderosa pine and thinleaf alder showed consistent growth in riparian settings. Despite being fenced from livestock, mortality of planted cottonwood and aspen was high, primarily because of heavy browsing by deer and elk.

Ken Fetcho is the effectiveness monitoring coordinator for the Oregon Watershed Enhancement Board, one of the main agencies overseeing the study area. He says that Wondzell's findings brought the importance of streamside planting into sharp focus: "Steve's findings helped us understand the importance of riparian revegetation efforts and how improved riparian vegetation will affect water temperature in a future changing climate."

LAND MANAGEMENT IMPLICATIONS

- Maximum temperatures already approach, and occasionally exceed, lethal thresholds for salmon and trout in many streams historically used for spawning and rearing throughout the interior Western United States.
- Climate change is expected to cause stream temperatures to increase as air temperature increases and changes in precipitation reduce streamflow, unless efforts are undertaken to mitigate these effects.
- Channel restoration alone, without riparian planting, is likely to exacerbate future stream temperature problems.
- Restoring and replanting riparian forest along streams where shade is lacking effectively cools streams and has the potential to mitigate the changes in stream temperature expected under future climates.

Strategic Plantings

Information from Wondzell's team, along with other data collected in the project, "made it evident that water temperature was the priority limiting factor for fish recovery in the Middle Fork of the John Day, and helped us understand the urgency of making a concerted effort to restore riparian vegetation along the river corridor," says Fetcho. "This information can help restoration practitioners, grant reviewers, and our board members understand what priority actions are needed to restore native fish in the mid-Columbia. We feel that these findings can be exported to other areas of the Mid-Columbia, including the Umatilla and Grande Ronde basins."

Joe Lemanski, the area's monitoring biologist with the Confederated Tribes of Warm Springs, says that Wondzell's findings go beyond highlighting the importance of shade. They also show how riparian revegetation plans for the area can be better targeted.

"Not all shade is considered equal," he says. "Steve's work lends to that point, demonstrating that shade in one place may be highly effective, yet 100 meters in either direction could prove to be useless based on channel form and the direction the river is flowing."

With that knowledge in hand, private landowners and state and federal agencies have been working together to develop a more strategic riparian planting and revegetation effort in high-priority areas, Lemanski says.

Steve Wondzell

Strategically placed riparian plantings along a meandering section of the Middle Fork John Day River.

Steve Wondzell

A mix of pine and native riparian hardwoods were planted in this section with the hope that in several decades the trees will be tall enough to shade the river, leading to cooler water for trout and salmon.

A Holistic Approach to Restoration

In addition to studying the effects of shade cover, Wondzell and his collaborators at Oregon State University also looked at the pros and cons of reconfiguring stream channels. Over the past 10 years, projects have reconfigured several miles of such stream channels along the Middle Fork John Day River by recreating curves in sections of the stream that had been dredge-mined or otherwise straightened. Wondzell says that reintroducing stream meanders can improve habitat by promoting biological complexity and possibly creating narrower, deeper channels that would promote cooler water temperatures. But in the short term it can also raise water temperatures because it increases the length of the stream channel and slows water velocity, thus exposing the water to more sunlight. The temperature change isn't much, he says, but it does make matters worse.

Not surprisingly, the answer is to coordinate these channel restoration projects with more riparian plantings that will put shade on the water. In fact, that's what is happening on the John Day restoration projects. The agencies collaborating in the Middle Fork John Day Intensively Monitored Watershed project have coupled riparian plantings with most of their channel restoration projects. In total, the agencies have installed 15 miles of streamside plantings and fenced 21 miles of stream to keep out livestock.

Wondzell says time is of the essence to plant trees alongside streams because their effectiveness in cooling temperatures shows so much promise. Each year, scientific information reveals the rapidity at which Earth's climate is warming. It's seen in the shrinking of mountain glaciers, in Antarctic ice floes, in the intensity of hurricanes, and in dozens of other ecological disruptions.

Is there enough time to make a difference in the Columbia River basin's salmon habitat? "That's a good question, with a complex answer," Wondzell says. Part of it is calculating how to direct the investment.

For example, focusing on planting conifers such as ponderosa pine would produce 100-foot trees within 120 years. Cottonwoods and aspen would grow much faster—reaching the same height in fewer than 80 years—but they're more vulnerable to deer and elk grazing. That's still a long time. Although 100-foot trees might be optimal, shade-bearing benefits would be seen at a third of that height, Wondzell says, and that's achievable in a decade or two.

Agnieszka Przeszlowska

A segment of the Middle Fork John Day River with streamside vegetation tall enough to shade and cool the water.

"It sounds simplistic, but it's a race against time," Wondzell says. "Everybody involved in this project—from universities to state and federal agencies to the Confederated Tribes of Warm Springs—sees the ticking clock of climate change."

If stream restoration gives hope for wild salmon, Wondzell says the efforts have to be made where they will count. Although the future looks daunting, "We have to try," he says.

"These fish are just barely hanging on," he adds. "But biology is a pretty amazing thing. These salmon have evolved over millennia. They've weathered amazing changes over that time and they're still here. Maybe with a little help, they'll still be here centuries into the future."

> *"The best time to plant a tree is twenty years ago. The second best time is now."*
>
> —Anonymous

WRITER'S PROFILE

John Kirkland has been writing about science, higher education, and business for more than 20 years. He lives in Portland, Oregon.

For Further Reading

Bergendorf, D. 2002. The influence of in-stream habitat characteristics on Chinook salmon (*Oncorhynchus tshawytscha*). Seattle, WA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest Fisheries Science Center. 46 p. https://www.nwfsc.noaa.gov/assets/11/7389_10232012_174142_Bergendorf2002.pdf.

Diabat, M. 2014. The influence of climate change and restoration on stream temperature., Corvallis OR: Oregon State University. 144 p. Ph.D. dissertation.

Diabat, M.; Haggerty, R.; Wondzell, S.M. 2012. Diurnal timing of warmer air under climate change affects magnitude, timing and duration of stream temperature change. Hydrological Processes. 27: 2367–2378.

Middle Fork IMW Working Group. 2017. Middle Fork John Day River Intensively Monitored Watershed: final summary report. 118 p. http://www.middleforkimw.org/uploads/6/7/8/9/67899115/mfimw-final-summaryreport.pdf.

Wondzell, S.M.; Diabat, M.; Haggerty, R. 2019. What matters most: Are future stream temperatures more sensitive to changing air temperatures, discharge, or riparian vegetation? Journal of the American Water Resources Association. 55 (1): 116–132. https://doi.org/10.1111/1752-1688.12707.

Science
FINDINGS

U.S. Department of Agriculture
Pacific Northwest Research Station
1220 SW Third Avenue
P.O. Box 3890
Portland, OR 97208-3890

Official Business
Penalty for Private Use, $300

PRSRT STD
US POSTAGE
PAID
PORTLAND OR
PERMIT N0 G-40

Scientist Profiles

STEVE WONDZELL, a research ecologist with the Pacific Northwest Research Station, studies the interactions among hydrological, geomorphological, and ecological processes that create, maintain, or modify aquatic and riparian habitats. He examines the ways in which these processes either interact with, or are affected by, land use practices. Wondzell has a Ph.D. in forest ecology from Oregon State University.

Wondzell can be reached at:

USDA Forest Service
Pacific Northwest Research Station
3200 SW Jefferson Way
Corvallis, OR 97331

Phone: (541) 758-8753
E-mail: steve.wondzell@usda.gov

Collaborators

Mousa Diabat, Oregon State University

Confederated Tribes of the Warm Springs

Oregon Department of Environmental Quality