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Science FINDINGS

INSIDE

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

Goldilocks and Coho Salmon: What Conditions Are "Just Right" for Migration and Spawning?

A researcher measures the volume of water flowing in a creek in the Smith River basin, Oregon. River discharge and temperature are two factors that influence spawning behavior of coho salmon. USDA Forest Service photo.

IN SUMMARY

*When the fall rains begin, the water volume in coastal streams in the Pacific Northwest increases, allowing coho salmon (*Oncorhynchus kisutch*) to move upstream and spawn. The common wisdom for many years has been that this increase in stream discharge is the main trigger that signals it's time for coho to begin their migration, build their redds (nests), and lay eggs, setting the stage for the next generation.*

But recent research by Rebecca Flitcroft with the USDA Forest Service Pacific Northwest Research Station shows that water volume is only half the equation. Coho salmon also need the water to be within a specific temperature range to move efficiently upstream. Like Goldilocks, they need water that's not too warm and not too cold, and they're happy to wait downstream until those conditions are met.

Flitcroft and her research team studied spawning sites in a subbasin of Oregon's Umpqua River to observe the combination of river discharge and temperature that prompted coho salmon to build their redds. They also compiled migration data from Winchester Dam on the Umpqua's main channel. They found that temperature—not river discharge—was the primary driver for coho salmon migrating through the main channel. A combination of temperature and discharge accounted for actual spawning activity.

The findings are of particular importance as climate change is expected to alter seasonal patterns in both temperature and river discharge in the coming years.

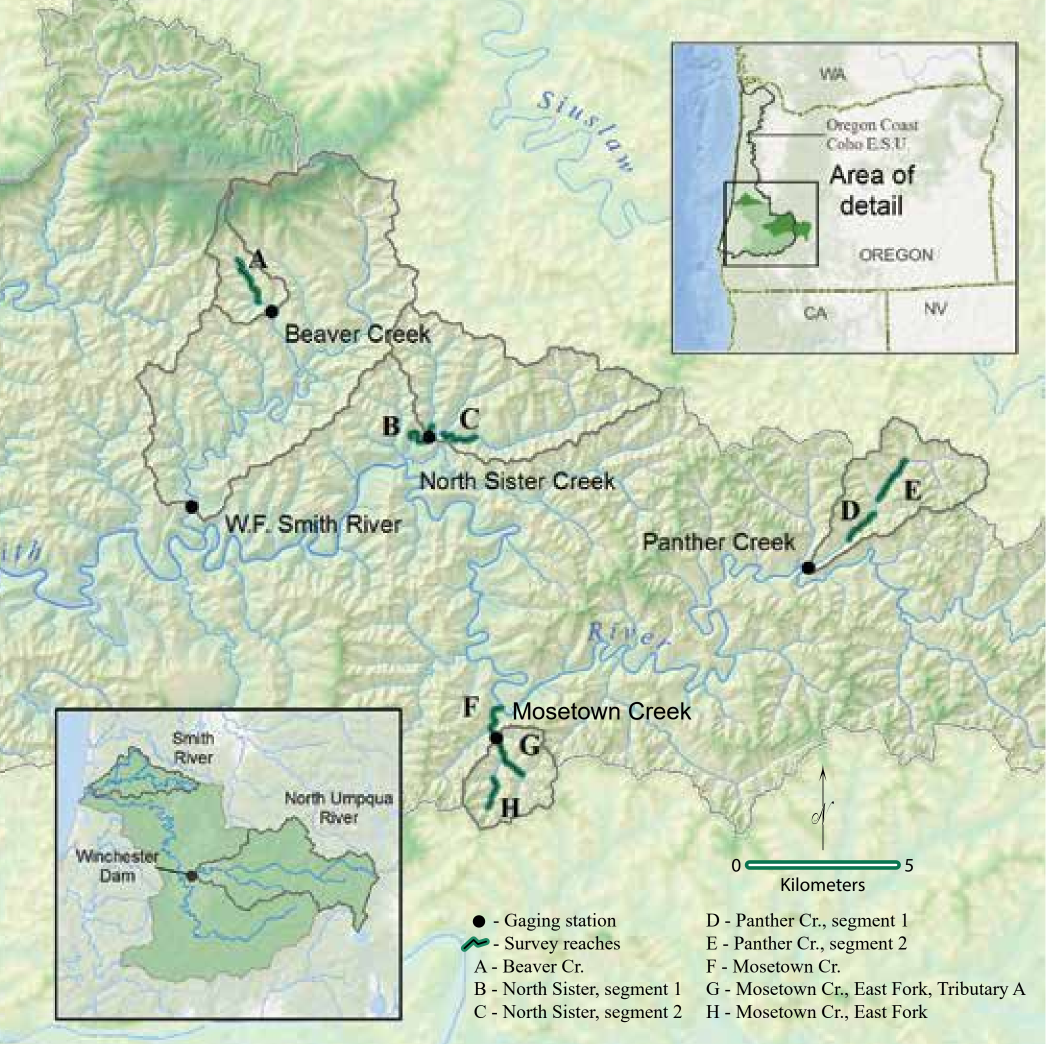
"Nature does not hurry, yet everything is accomplished."

–Lao Tzu

As summer turns to fall, Pacific coastal coho salmon (*Oncorhynchus kisutch*) start making their way from the ocean into freshwater estuaries and begin their migration to their spawning streams. The fish need to be ready to move onto gravel beds in streams where they build their redds (nests) and deposit their eggs once the rains begin. Rain raises the water level in the streams, providing access to these important areas.

The link between fall rains and salmon migration has been a reliable signal for predators of all kinds—whether they be on two legs or four—that good fishing opportunities are on their way.

But recent research by Rebecca Flitcroft, a research fish biologist with the USDA Forest Service Pacific Northwest (PNW) Research Station shows that water volume isn't the only factor. Coho salmon need the right combination of river discharge and water temperature—a kind of Goldilocks effect that maximizes their success in reaching their spawning grounds. If the water is too warm—



A map of spawning study sites in the Smith River basin. The inset shows the location of Winchester Dam. From LovellFord et al. (2020).

regardless of the amount of flow—they will wait for conditions to change. What they want is something that's … *just right*.

Flitcroft has been studying this for several years. A 2021 Science Findings article examined her research into the overall life cycle of coho salmon and how it's affected by the combination of temperature and flow. She was able to graphically illustrate coho salmon's migratory patterns under specific conditions of temperature and flow, showing that they did indeed concentrate most of their migratory behavior when conditions were optimal.

Flitcroft's current research focuses specifically on spawning behavior. Her aim is to answer questions such as, How do the fish know it's time to return? What are the environmental cues for their return? Are cues different at different places in their long return migration from the ocean to small streams for spawning? And once they are on the spawning grounds, do environmental conditions link with spawning initiation?

"Knowing the answers is critical in the development of fishing regulations, habitat protection, and restoration actions for this imperiled fish," Flitcroft says. "It's particularly relevant under climate change, which is affecting both thermal conditions and the timing and intensity of river discharge events."

Migration and Spawning

Flitcroft teamed up with Rachel LovellFord, who at the time was a student in the Water Resources Graduate Program at Oregon State University, and the program's director, Dr. Mary Santelmann, to study two areas of the Umpqua River drainage in southwest Oregon. These sites were selected so they could study both midriver migration and spawning. One site was the Winchester Dam, located above the main confluence of the North and South Umpqua River. The dam was built in 1890 and contained power-producing turbines until 1923. Since then, its main function has been water storage. A fish ladder has been maintained at the dam since 1945. The researchers chose this site because it's set up with monitoring and data collection equipment that track the migration of salmon. The entire North Umpqua population of coho salmon must pass through Winchester Dam to reach spawning locations upstream, making this a perfect site to study midstream salmon migration.

The second site was the Smith River basin, which drains into the lower Umpqua about 50 air miles below Winchester Dam. There, the researchers identified spawning sites that had long-term data collected by the Oregon Department of Fish and Wildlife and set up gages that measured temperature and river discharge. Here they could directly study spawning conditions and behavior, as opposed to the midriver migration data they were collecting at Winchester Dam.

Gages such as this one in Beaver Creek, within the Smith River drainage, were positioned to measure temperature and river discharge. USDA Forest Service photo.

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"A lot of sediment moves through the smaller streams of the Coast Range, so installing and maintaining gages is really labor intensive," Flitcroft says. "Some of our gages from years ago have blown out or have been buried in sediments."

The dynamic nature of stream habitats in the Oregon Coast Range presented a challenge to maintaining equipment over time. Sometimes the team would revisit a gage at a spawning site and find that what was once a deep pool was now full of gravel and dry, requiring them to move the equipment to a different location.

Because they maintained gages that measured both temperature and discharge at spawning sites, the researchers now have a rich record of conditions and spawning behavior.

"We have one of the largest datasets of discharge and temperature at spawning sites in Oregon, going back 11 years," she says.

Key Findings

- Water temperature, rather than river discharge, was more closely linked to the upstream migration of coho salmon in the mainstem of the North Umpqua River. Most of the adult fish migrated through the mainstem before the onset of winter rains.
- Coho salmon began spawning in small tributary streams of the Smith River basin in response to a combination of higher discharge and lower water temperature. Spawning began after initial high-flow events in the fall but only after stream temperature fell below 53 °F.
- At spawning sites, discharge and temperature metrics were important in explaining the timing of redd (nest) construction throughout the spawning period. However, the same metrics were not consistently important in every subbasin. Water temperature was important in explaining redd construction in the largest subbasin, and discharge metrics were consistently important in the smallest.
- Multiyear variability in stream temperature was more closely linked to variability in air temperature and solar radiation than to the presence of instream restoration structures designed to create pool habitat and capture sediments.

What Is Just Right?

To make sense of the data, it's helpful to know what conditions salmon need to spawn.

"Spawning, more than migration alone, has very specific requirements for coho salmon," Flitcroft says.

At minimum, they need enough water to physically get on the gravel beds where they will make their redds. At some parts of the year, the water in spawning areas is shallow or nonexistent, hence the need for the fish to wait until winter rains inundate the watersheds of the Coast Range.

"The water must be high enough, but it can't be too high. They don't like to spawn in pools," Flitcroft says. "Coho females dig into the gravel at a depth where eggs can be oxygenated and also protected from winter scour events when high flows move the gravel on the riverbed. Spawning locations need to be just right for fish to hatch and survive through late winter and spring storms and flooding."

So, not surprisingly, the scientists found that river discharge—the amount of water flowing through a spawning stream—was an important factor in spawning behavior. But so was water temperature. And here, things get complicated.

Flitcroft and her team found that discharge was consistently a more important factor at the smaller spawning sites, whereas temperature was more important at the larger sites. Flitcroft hypothesizes that the geology and morphology at each of the sites were slightly different from each other and that the deciding factor in a salmon's decision to use one site over another comes down to a combination of flow and temperature.

A juvenile coho salmon. Photo by ©Kristen Kirkby.

While discharge is tied to the mechanics of building a redd, temperature is tied to coho salmon physiology. Like other living things, coho function best within a specific temperature range, in this case 45 °F to 60 °F for spawning.

"If it's too cold, the eggs won't develop. If it's too warm, adults' hearts can't keep up, so they can't move upstream quickly," Flitcroft says.

So, while coho can display a lot of variability in their behavior—adjusting their migration timing to fit optimal conditions, for example—their physiology is more hardwired.

The scientists compiled data at the Smith River sites by plotting together the flow data, temperature, and the number of redds. At each site, the start of spawning occurred after the onset of the fall rains—which created a higher level of flow—but only after stream conditions fell below a threshold of about 53 °F.

Contrast those findings with the data collected at Winchester Dam, which measured mainstream migration through the river before spawning occurred. Here, the scientists found that thermal conditions were the deciding factor. Most coho salmon traveling upstream past the dam did so when the water started to cool but before the onset of winter rains, typically between November and February. No migration happened until the water temperature dropped below 64 °F.

This gets back to the fish's physiology; coho salmon move most efficiently within a specified temperature range. The lower temperature gave the fish the signal to start moving upriver, but only when the discharge level was sufficient did they begin making their redds.

This goes against—or it's at least a refinement of—the theory that prevailed for decades about coho migration and spawning behavior. The old theory was that discharge alone was the deciding factor: that the whole migration and spawning process happened only after the onset of rain.

"We observed that just considering discharge wasn't a complete enough picture," Flitcroft says.

"We knew there was a range of temperatures in the river, but as an actual cue for spawning, it was not something we looked at before."

Effects From Stream Enhancement Projects

The new research not only looked at the interplay between discharge and temperature, but it also addressed the factors that affect water temperature, namely the surrounding air temperature and the amount of sunlight hitting the water.

Stream enhancement projects—primarily the placement of logs and boulders in streams to create pools, promote habitat complexity, and encourage the deposition of gravel—have been employed in Oregon Coast Range streams for decades. Agencies involved in these projects, such as the U.S. Department of the Interior, Bureau of Land Management (BLM) and the Oregon Department of Fish and Wildlife, monitor the success of these projects, including placing instruments to see how the projects affect water temperature.

Flitcroft teamed up with Santelmann and her graduate student, Greer Harewood, to look at South Sister Creek, another subbasin of the Umpqua River drainage, where more than 90 enhancement structures were installed between 2007 and 2009. In all, the BLM and the Smith River Watershed Council placed more than 15,000 boulders and 400 logs at these sites.

Flitcroft's team looked at the data from temperature gages at the sites and found that while the projects did create more pool habitat for coho salmon, they did little to change the water temperature. Any differences in the water temperature over the years were due to differences in the temperature of the air.

"It's important because one of the outcomes people assumed might happen with stream restoration projects is a change in the thermal regime. But there was no correlation," Flitcroft says. "If the water was cooler in some years, it had much more to do with the fact that it was a generally cooler year."

John Colby, a hydrologist with the BLM's Coos Bay District, worked with Flitcroft's research team in studying the enhancement sites.

"The findings are challenging our assumption about cooling streams with instream structures," he says.

"We're seeing that individual, separately placed structures can create relatively cool site-scale water temperatures, but they cannot cool an entire drainage. With greater connectivity between structures, the beneficial effects on temperature can accumulate, but these processes can take years to decades," he says.

In the meantime, the research project has prompted the BLM to improve and broaden its data collection to get a more accurate picture of what's happening on the river.

"It's making us pay closer attention to the data we collect and that the data is viable and usable into the future," he says.

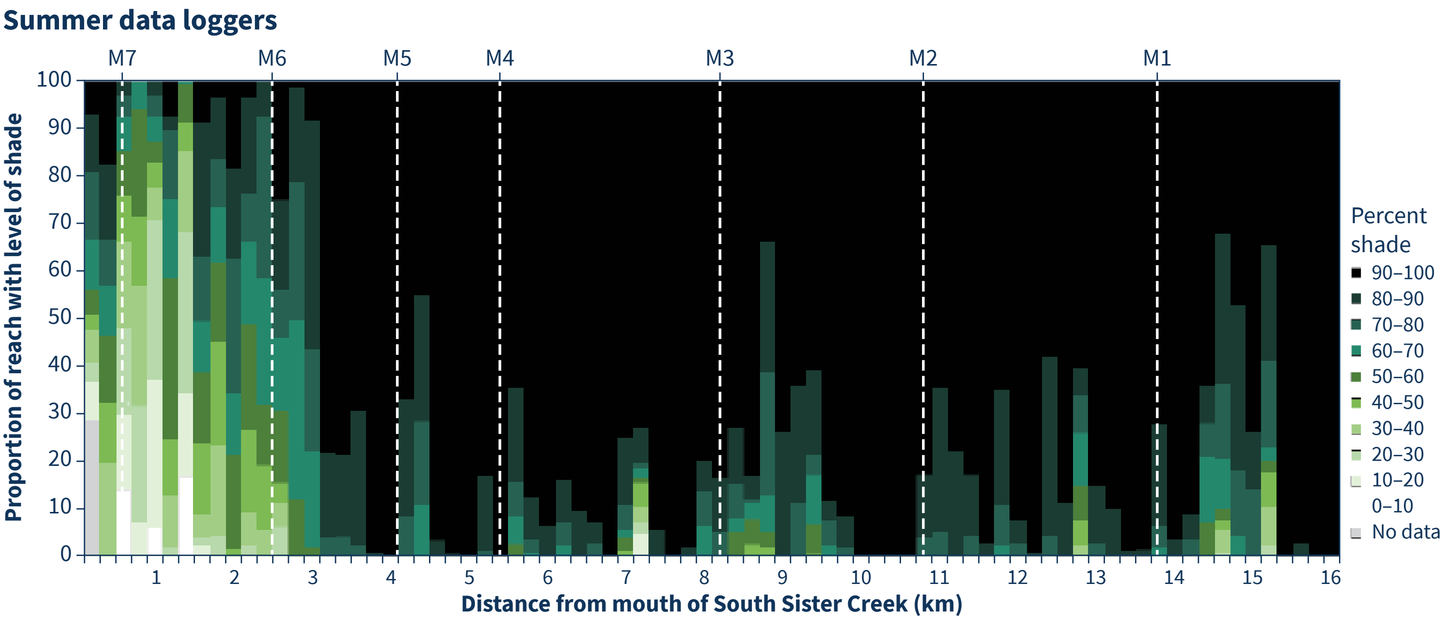
The Changing Climate

Climate change is altering environmental patterns in the Pacific Northwest. And this will affect native coho.

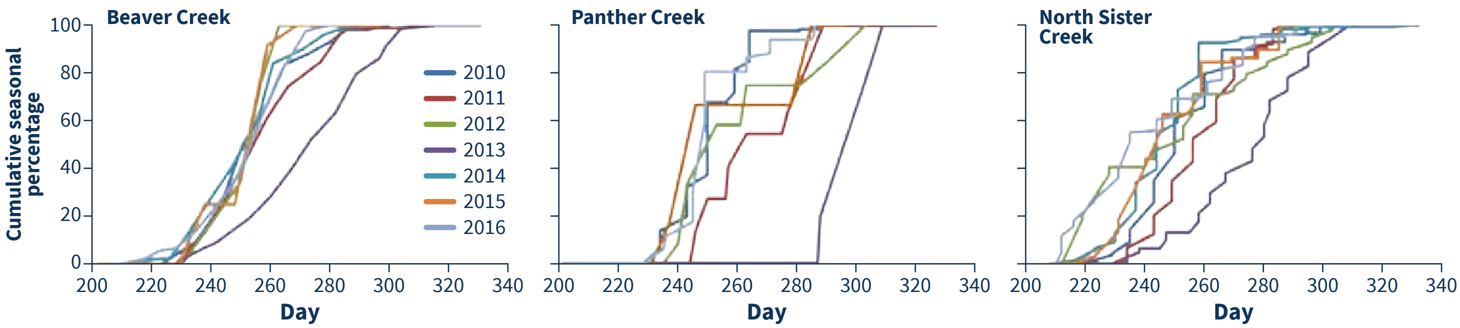
Air temperatures are rising, which will influence the temperature of streams. As summers

LAND MANAGEMENT IMPLICATIONS

- Information about the environmental cues that influence migration and spawning of coho salmon in the Oregon Coast Range can be used in protection planning for this imperiled species.
- Understanding relationships between the timing of redd construction and characteristics of the hydrological regime are critical to assess potential future climate effects on spawning of Oregon coastal coho salmon.
- Instream structures can create cool microhabitats, but they have little influence on mean stream temperature in heavily shaded stream reaches.



Measurements of shade on South Sister Creek (within the Umpqua River basin). Darker colors represent more shade. The least amount of shade was measured near the mouth of the creek. Overall, more than 67 percent of the creek was shaded for most of the day, from the mouth to 16 kilometers upstream. From Santelmann et al. (2022).



A record of cumulative daily redd construction at Beaver Creek, Panther Creek, and North Sister Creek, by year. In 2013 (purple line), falls rains came later than in other years, and spawn timing was strongly delayed across all sites. From Butler et al. (2020).

become drier and longer, the fall rains will start later in the year. Meanwhile, Flitcroft says, winters on the Oregon Coast are becoming stormier, which affects the water volume and turbulence in the streams.

The longer, drier summers will likely cause delays in adult coho moving upstream to spawn, Flitcroft says. Research already proves this point. A collaborative study Flitcroft conducted with Oregon State University graduate student Mackenzie Butler and professor Guillermo Giannico examined seven years of spawning, river discharge, and temperature data available at three subbasins of the Umpqua. They found a distinct delay in redd construction in 2013, a drought year when the onset of autumn rains was later than in other years.

"They can't spawn if there's no water, and they can't spawn if it's too warm," Flitcroft says.

Delays in spawning will mean delays in the emergence of young fish. What kind of environment will they face when they emerge?

"Are they going to be emerging in stormy conditions or dry conditions? Will insects be available, or will they be emerging in the middle of winter?" she says.

Managers of hydroelectric dams can release water in times of need, creating more discharge for migrating salmon. But Winchester Dam doesn't have that capability, so along the Umpqua River other solutions will be needed. Knowing the freshwater conditions that coho salmon need to survive can be a starting point in figuring that out.

"If there is magic on this planet, it is contained in water."

–Loren Eiseley

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

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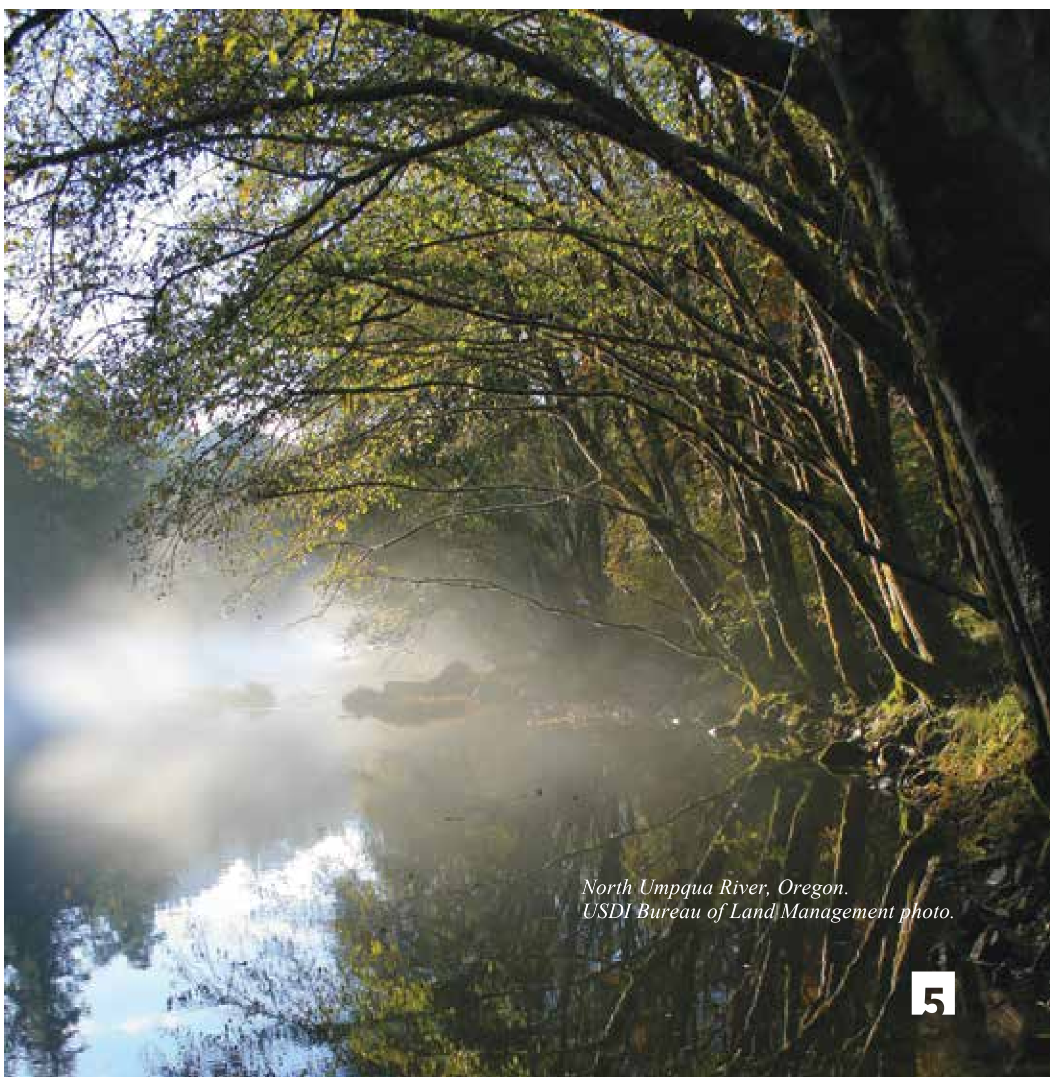

North Umpqua River, Oregon. USDI Bureau of Land Management photo.

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Scientist Profile

REBECCA FLITCROFT is a research fish biologist with the Pacific Northwest Research Station. She earned her Ph.D. in fisheries science from Oregon State University. Her four primary lines of research include multiscale salmonid ecology, stream network analysis, climate change and salmonid life history, and integrated watershed management. She is particularly interested in statistical and physical representations of stream networks in analysis and monitoring to more realistically represent stream complexity and connectivity for aquatic species.

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