

Science

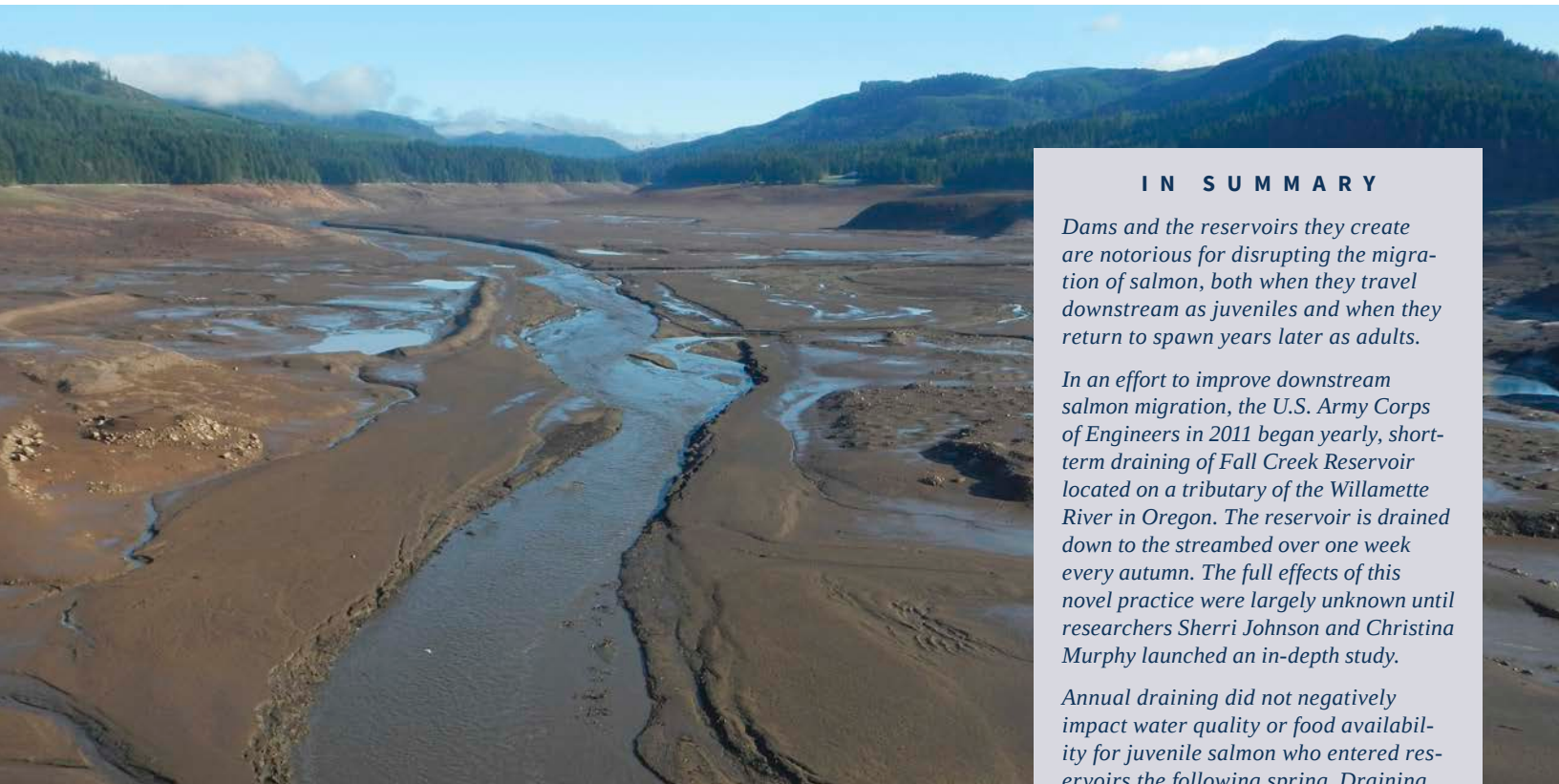
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"Science affects the way we think together."
Lewis Thomas

Pulling the Plug: Annually Draining a Reservoir to Help Salmon



Fall Creek Reservoir, Oregon, after a December draining. The annual drawdowns have reduced the number of nonnative fish that previously preyed on juvenile salmon. Photo by Sherri Johnson, USDA Forest Service.

The health of the environment is good if the salmon and steelhead are around. It is that simple.

—Tom McCall, Oregon governor, 1967–1975

Dams serve many purposes, including flood management in the winter, water storage in the summer, and power generation. The reservoirs they create are havens for recreational fishing, boating, and swimming. But they've always been a problem for anadromous fish, such as the endangered Chinook salmon (*Oncorhynchus tshawytscha*).

Juvenile salmon emerging from their spawning and winter-rearing habitats upstream find themselves in an artificially warm environment when they reach the reservoir downstream. Although the reservoir provides plenty of food, the warm water and lack of flow makes juvenile salmon vulnerable to parasites and diseases. The young salmon are also preyed upon by invasive species, such as largemouth bass, bluegill, and crappie. Passage out of the reservoir is challenging and hazardous. The dam can delay downstream migration for months or years, and it forms a difficult barrier for adult salmon when making their way back to spawning grounds after years in the ocean.

IN SUMMARY

Dams and the reservoirs they create are notorious for disrupting the migration of salmon, both when they travel downstream as juveniles and when they return to spawn years later as adults.

In an effort to improve downstream salmon migration, the U.S. Army Corps of Engineers in 2011 began yearly, short-term draining of Fall Creek Reservoir located on a tributary of the Willamette River in Oregon. The reservoir is drained down to the streambed over one week every autumn. The full effects of this novel practice were largely unknown until researchers Sherri Johnson and Christina Murphy launched an in-depth study.

Annual draining did not negatively impact water quality or food availability for juvenile salmon who entered reservoirs the following spring. Draining caused predatory fish to shift their diets away from salmon fry and reduced invasive fish to a point where, today, virtually none remain in the reservoir.

It's not clear if reservoir draining alone will lead to more returning adult salmon, but the researchers are confident that it is a net benefit for downstream migration, a necessary step in the salmon lifecycle.

This research is being used to evaluate future dam management scenarios, including improving fish passage downstream, changing water levels associated with climate change and drought, and drawdowns for maintenance.

For this and a host of other reasons—some environmental and some related to the hazards and costs of aging infrastructure—more than 900 dams across the country were removed between 1995 and 2015. By 2015, the rate was 50 to 60 dams removed per year.

At the Fall Creek Dam on a tributary of the Willamette River about 30 miles east of Eugene, Oregon, the U.S. Army Corps of Engineers has drained the reservoir every year since 2011. The goal was to help young salmon make their way downstream without having to remove the dam. The dam is drained over the span of one week in the fall, bringing the water level all the way down to the streambed. The juvenile salmon—along with many other species of fish in the reservoir—are essentially flushed downstream.

This isn't the only way the salmon can escape the reservoir. The dam, which was built in 1966, is equipped with outlets at varying depths—called fish horns—through which young salmon can pass. But during construction, the size of the outlets didn't account for the unexpectedly large size of the young salmon. When living in a reservoir, the young salmon grow twice as large as they would if they remained in streams. The larger salmon can pass downstream through the fish horns, but they get injured and many die. Dam managers say the salmon also appear to have a hard time finding the fish horns in the first place. The main outlet at the bottom of the dam that is used to drain the reservoir is larger and provides a smoother ride, resulting in a higher survival rate.

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SM.FS.pnw_pnwpubs@usda.gov
Rhonda Mazza, editor; rhonda.mazza@usda.gov
Jason Blake, layout; jason.p.blake@usda.gov

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Key Findings

- Short-term draining of Fall Creek Reservoir in Oregon—to aid downstream migration of juvenile salmon—drastically reduced nonnative predators such as largemouth bass and crappie.
- Predatory fish that remained after the draining showed unprecedented shifts in diet. They consumed fewer juvenile salmon and more phytoplankton, zooplankton, and other invertebrates. Meanwhile, the food base for juvenile salmon remained resilient after draining.
- This unusual dietary shift among top predators within a food web has rarely been documented outside of a laboratory.
- The annual draining did not negatively affect water quality downstream over the long term, or within the reservoir upon refilling.

Has it helped? Have there been unintended consequences?

That's what Sherri Johnson, a research ecologist with the Pacific Northwest Research Station, and Christina Murphy, then a Ph.D. candidate at Oregon State University, wanted to find out. Together they began a multiyear study of the reservoir's food web and analyzed more than a decade of data gathered by the U.S. Army Corps of Engineers and the Oregon Department of Fish and Wildlife (ODFW) to get a fuller picture.

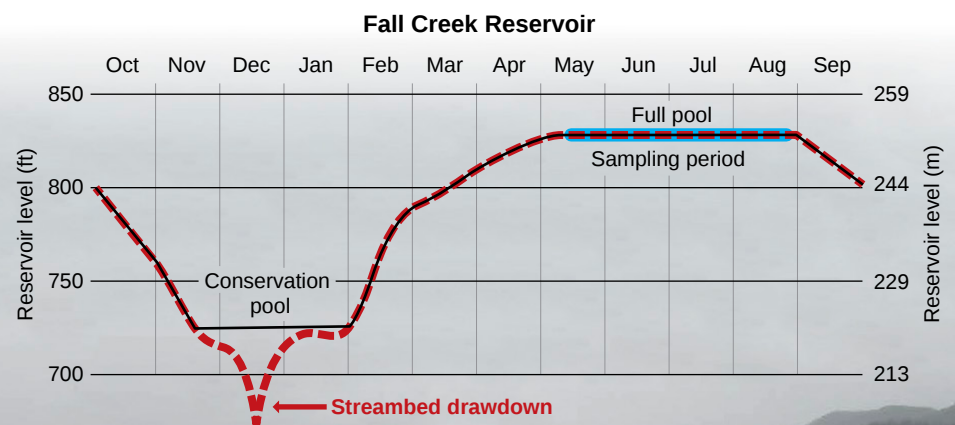
The annual draining of the reservoir gave Johnson and Murphy a readymade laboratory.

"Scientists rarely get the opportunity to design a large landscape-scale experiment for their own study purposes, but through this project, we were able to quickly study what the [U.S. Army] Corps of Engineers had been doing and to answer key questions about reservoir ecosystems," Johnson said.

Going With the Flow

For one portion of their study, the scientists examined 12 years of data on juvenile salmon captured in traps downstream of the dam by the U.S. Army Corps of Engineers. The numbers showed that most of the salmon, in the years before annual draining started, exited the dam from October to February, presumably through the fish horns. Once annual draining began, 95 percent of the salmon exited by mid-November. This indicated that most of the salmon had exited through the dam's main outlet, largely avoiding the fish horns altogether. The upshot was that the new method of flushing salmon downstream likely provided a safer passage and increased survival.

The researchers and managers recognize a possible downside to the timing, however. When the salmon were spreading their migration over several months, it provided a type of natural safeguard that evened out their exposure to certain short-term stream conditions, presumably boosting the overall survival



Schematic of the monthly water levels in Fall Creek Reservoir. The water level is managed to meet multiple-use guidelines established by the U.S. Army Corps of Engineers.



The reservoir is drained through its main outlet. This flushes fish from the reservoir and helps juvenile salmon migrate downstream. Photo by Sherri Johnson, USDA Forest Service.

rate of the population. By compressing that timeframe to just one week, that safeguard disappeared. However, the scientists have not examined the long-term implications, so it remains to be seen whether the compressed timing is a problem.

Menu Change for Predators

During the summer months of 2013 and 2014, after the reservoir was drained then refilled, the scientists collected tissue samples from resident fish—not only salmon, but their predators, including bass, bluegill, crappie, and pike minnow, as well as native rainbow trout. They compared these tissue samples with those collected from resident fish at nearby Hills Creek and Lookout Point reservoirs that had not undergone annual draining. The level of nitrogen isotopes in the tissue samples showed what the fish had been eating at Fall Creek and

how they differed from the fish at the other reservoirs.

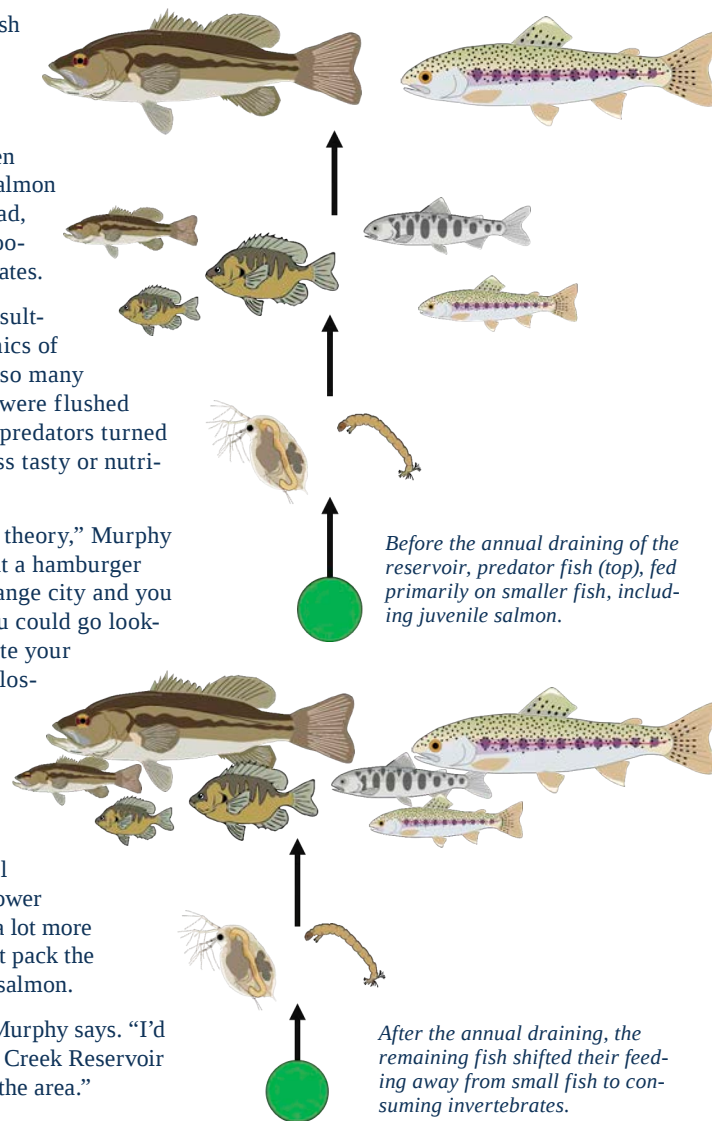
The tissue analysis revealed that the nonnative fish in the Fall Creek Reservoir had eaten comparatively fewer young salmon and fish in general and, instead, eaten more phytoplankton, zooplankton, and other invertebrates.

This shift in the food web resulted from the changing dynamics of Fall Creek Reservoir. When so many salmon and other small fish were flushed during the fall draining, the predators turned to more abundant, even if less tasty or nutritious, food options

“It’s called optimal foraging theory,” Murphy explains. “Let’s say you want a hamburger for lunch, but you’re in a strange city and you only have an hour break. You could go looking for one and possibly waste your hour, or you could find the closest restaurant and eat something else.”

For the predators, encountering a Chinook salmon took more effort, and the odds of finding a prey-sized fish at all became slim. Suddenly, the lower invertebrates started to look a lot more appetizing, even if they didn’t pack the nutritional punch of a young salmon.

“It’s a game of probability,” Murphy says. “I’d rather be a salmon in the Fall Creek Reservoir than in some of the others in the area.”



Drained Fall Creek Reservoir with “fish horn” outlets designed to allow juvenile salmon to migrate downstream when the reservoir is filled. Photo by Christina Murphy, Oregon State University.



Researcher Christina Murphy collects a plankton sample from Fall Creek Reservoir. She collected similar samples from other reservoirs in the Willamette basin to better understand how annual draining affected reservoir food webs. Photo by Brendan Coffin, Oregon State University.

Jeremy Romer, assistant district fish biologist for the ODFW in Springfield, worked with Murphy and Johnson on the Hills Creek and Lookout Point research. They determined that bass, walleye, and other warmwater fish eat young salmon in large numbers when they're available. Romer calls the bass "ambush predators" that gather at the headwaters of the reservoir, striking when the young salmon enter from upstream. So while the predator species at Fall Creek were shifting their diets lower on the food chain, the research showed predators

at Hills Creek and Lookout Point were still feasting on nitrogen-rich salmon fry.

"Predation on native juvenile salmon throughout the state has prompted ODFW to make changes in fishing regulations associated with nonnative species, including removing limits on bass in free-flowing waters. Recent studies, such as those conducted by Murphy and Johnson in the upper Willamette basin reservoirs, help to inform fish management decisions," Romer said.



Christina Murphy collects a water and sediment sample from the drained Fall Creek Reservoir. Photo by Sherri Johnson, USDA Forest Service.

New Reservoir Dynamics

Not only did draining the Fall Creek Reservoir result in a shift among the predators, eventually it virtually eliminated them from the reservoir altogether. The scientists discovered this by capturing fish within the reservoir over subsequent summers after the first draining in 2011.

"In 2012, we could capture 10 bass an hour," Murphy says. "This went down each year: by the summer of 2015, we only caught one during all of our sampling; and in 2016, we didn't catch any. This change was also reflected in the data from the downstream trap. The same decline occurred for crappie, but faster."

"It took about 4 years, but now the reservoir community is dominated by native species," Murphy says. "If there are any largemouth bass left in the reservoir, their numbers are so low that we can't detect them."

Looking Downstream

Young salmon aren't the only species flushed from the reservoir into Fall Creek. Largemouth bass, bluegill, and crappie are too. These nonnative fish thrive in relatively warm, still waters such as reservoirs, but they appear to not do well in cold, swift-moving streams. Their survival drops as they enter a new hostile environment.

"The reservoir environment is what allows the warmwater fish to thrive, and if you take that away there will be fewer of them," Romer says.

The juvenile salmon, on the other hand, fare much better. They are entering the environment where nature intended them to be.

Murphy examined the downstream river reaches following the drainings. The first year, she and fellow biologists found some populations of bluegill and other nonnative fish in the river below the reservoir. The following summer, the researchers found no nonnative fish downstream from the reservoir.

Will Reservoir Draining Lead to More Salmon?

Draining the reservoir seems to help salmon in their downstream migration and vastly lessens the impact of predatory fish. But is it producing more returning adults?

It could be, but the answer is far from conclusive.

The U.S. Army Corps of Engineers counts every adult salmon that returns to a collection facility at the base of the Fall Creek Dam. Johnson and Murphy started examining the number of adult Chinook returning in 2015. This was 4 years after the first draining, and the year that the cohort of juvenile salmon

from that initial flush would be returning as adults ready to spawn. The researchers expected to see an increase in salmon returns but were surprised that the numbers remained fairly constant compared to the years before annual reservoir draining. At least that was the case through 2018 when they published these findings.

By 2020, the number of returning wild spring Chinook was the highest in the dam's history, according to Gregory Taylor, supervisory fisheries biologist for the U.S. Army Corps of Engineers, which operates the dam. He thinks the main driver in the big return was a correspondingly big number of juveniles released from the dam 4 years earlier. He also acknowledges that many factors are at play, making it hard to single out one—the biggest factor perhaps being the ocean conditions where the fish live most of their adult lives.

"There are only so many things we can control," Taylor says. "We feel really confident that the things we have control over have worked. At the end of the day, we are just trying to get out as many juveniles as we can."

Johnson agrees: "One act can't fix it all, but increasing the outmigration is a start."

To that end, the scientists developed GrowChinook (<http://www.reservoirwebs.org/p/growchinook-model.html>). The online modeling tool can help land managers evalu-

LAND MANAGEMENT IMPLICATIONS

- Annual, short-term draining and refilling of reservoirs may effectively reduce invasive fish species in reservoirs without negatively affecting juvenile salmon.
- Because juvenile salmon that feed in reservoirs grow nearly twice as big as the ones in streams, the original reservoir outlets for downstream passage were too small. Draining the reservoir allowed fish to pass through a larger outlet, resulting in reduced injury and mortality.
- Draining a reservoir over a one-week period and as a result sending nearly all fish downstream reduced the numbers of fish that preyed on juvenile salmon.
- To help land managers explore scenarios that factor into the effects of climate change, drought, and reservoir management on juvenile salmonids, researchers developed the online tool GrowChinook (<http://www.reservoirwebs.org/p/growchinook-model.html>).

ate future management scenarios, including how potential changes in water availability associated with climate change, drought, or drawdown for dam maintenance, might affect juvenile salmon and their food webs.

Taylor says Johnson and Murphy's research shows that draining the Fall Creek Reservoir is a net positive for salmon. But it may not be the right practice for all reservoirs.

"Each site is a slightly different scenario, so a full drawdown won't work everywhere," Taylor says. For example, in late fall, normal drawdowns have already lowered the water level at Fall Creek Reservoir to a point where

a full draining won't overwhelm the creek below. That's not the case in many other reservoirs, he says, and some dams don't have the kind of outlet that allows for a full drawdown.

"But it's definitely giving us food for thought about how we do things," he says. "With the work Johnson and Murphy have done, we now have a much more rigorous evaluation of the plusses and minuses of reservoir draining."

*Turn off your mind,
relax, and float downstream.*

—John Lennon

For Further Reading

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Writer's Profile

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



Pacific Northwest Research Station
USDA Forest Service
1220 SW 3rd Avenue, Suite 1400
Portland, OR 97204

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Scientist Profiles



SHERRI JOHNSON is a supervisory research ecologist with the USDA Forest Service Pacific Northwest Research Station in Corvallis. Her areas of specialty include forest-stream interactions; the influences of hydrology, stream temperature, and biogeochemistry on food web dynamics;

and the effects of disturbances, including climate change, drought, and floods, on aquatic ecosystems. She earned a bachelor's degree in environmental biology at the University of Montana and a master's and Ph.D. in aquatic ecology at the University of Oklahoma.

Johnson can be reached at:

USDA Forest Service
3200 SW Jefferson Way
Corvallis, OR 97331-8550

Phone: (541) 758-7771
E-mail: sherri.johnson2@usda.gov

Collaborators

Greg Taylor, U.S. Army Corps of Engineers

Rose Wallick, U.S. Geological Survey Oregon Water Science Center

Ivan Arismendi, Oregon State University



CHRISTINA A. MURPHY is an assistant leader with the U.S. Geological Survey's Maine Cooperative Fish and Wildlife Research Unit. She is also an assistant professor in the Department of Wildlife, Fisheries, and Conservation Biology at the University of Maine. She earned her Ph.D.

from Oregon State University where she worked on the Fall Creek Reservoir project with her then advisor, Sherri Johnson. Her research is focused on the ecological implications of changes to the availability and timing of water, and to the introduction of novel species and disease.

Murphy can be reached at:

Maine Cooperative Fish and Wildlife Research Unit
University of Maine, 5755 Nutting Hall, Room 210
Orono, ME 04469

Phone: (207) 581-3010
E-mail: camurphy@usgs.gov

Oregon Department of Fish and Wildlife

Oregon Department of Environmental Quality

National Oceanic and Atmospheric Administration