



Fire in the riparian vegetation during the 2007 East Zone Complex, Payette National Forest, Idaho.  
Credit: Payette National Forest.

## Wildfire, Prescribed Fire, and Peak Stream Flow: Understanding Effects on Stream Habitats and Communities

### *Summary*

Much of the previous research on wildfire's effects on stream communities has examined biotic responses in burned versus unburned watersheds (catchments). But we know that fires burn in a mosaic pattern of differing severities across the landscape, depending on topography, aspect, vegetation, weather, and other factors. Scientists evaluated the gradient of burn severity among watersheds in a dry Intermountain West ponderosa pine forest in central Idaho to gauge the relative response of stream communities under a range of burn severities. They observed a gradient of both habitat and biotic effects correlated with a gradient of burn severity. Effects varied based on interactions of annual stream flow patterns and burn severity of the streamside forest. Macroinvertebrate communities in burned areas did not stabilize within 4 years after fire, nor did they become similar to communities in unburned areas.

With this expanded knowledge of wildfire's effects on streams, the scientists compared the stream ecosystem effects of a prescribed burn to only those watersheds that burned at low severity in wildfire. They found that the prescribed fire conducted in the spring when fuels were moist had negligible effects on stream communities. However, even the lowest severity wildfires produced changes in stream communities. They concluded that prescribed fire effects in these forests on stream communities are negligible, at least when the riparian forest is not burned.

## Key Findings

- Habitat changes varied based on interactions of annual stream flow patterns and burn severity of the streamside forest.
- Changes in habitat were correlated with instabilities in macroinvertebrate communities.
- Macroinvertebrate communities in burned areas did not become similar to communities in unburned areas within 4 years after fire.
- Springtime prescribed fire effects on stream ecosystems were negligible and even lower than the effects observed after low severity wildfire.
- Riparian forest burn severity and extent were lower after prescribed fire than after wildfire, which may explain observed patterns.

## Fire, flow, and stream communities

Fire, with the erosion, snag-fall, debris flows, and increased light that it brings, is an important disturbance in western forests and riparian areas. For example, debris and gravel can create pools and provide fish spawning beds. Uneven, patchy burns often create habitat heterogeneity, thereby increasing biodiversity in streams and riparian forests.

*“We really do not have a good understanding of how fires of different severities and extents influence stream ecosystems”*

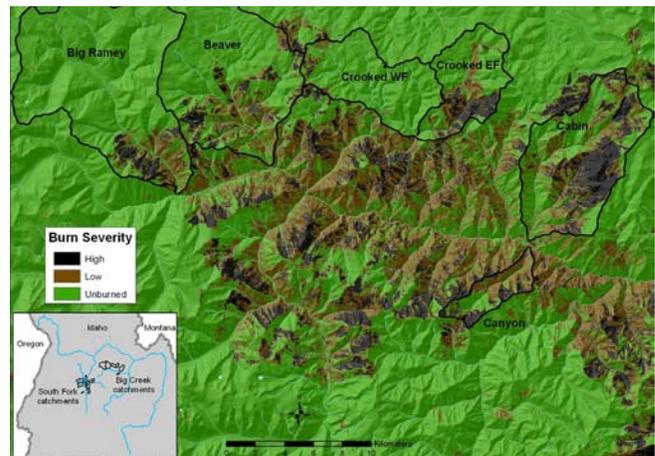
“We really do not have a good understanding of how fires of different severities and extents influence stream ecosystems,” says David Pilliod, research ecologist with the U.S. Geological Survey in Boise, Idaho.

Pilliod headed a research team in Idaho that sought to determine if changes in macroinvertebrate communities stemmed from riparian fires alone or instead resulted from the interaction of burn severity and annual variability in peak stream flow. Two research zoologists with the U.S. Geological Survey conducted similar research—Bruce Bury in Corvallis, Oregon, and Steve Corn, in Missoula, Montana. Pilliod, Bury, and Corn suspected that the interaction of burn severity and annual peak stream flow was more important than either variable alone. They also suspected that habitat conditions and stream-bottom insect (also called macroinvertebrates, and including caddisflies, stoneflies, mayflies, midges) communities post-wildfire did not become more like those in unburned streams over time.



Researcher David Pilliod, U.S. Geological Survey, working in Big Creek drainage, Idaho.

The researchers used pre- and post-fire satellite imagery to estimate burn severity because the patchy pattern of burns throughout the forest is likely to influence biotic responses. They compared streams along a gradient of burn severity and extent in the Big Creek drainage of central Idaho with nearby unburned streams in the South Fork Salmon River system.



Map of burn severity for each catchment in the Big Creek drainage based on Normalized Burn Ratio calculated from Landsat satellite imagery.

Prior to 2006 and 2007, the South Fork Salmon stream watersheds had seen no stand-replacing wildfires for 60–75 years, so annual peak stream flow was probably the major disturbance there. The Big Creek drainage is mainly within the Frank Church–River of No Return Wilderness Area, where wildfires are not suppressed, so parts of many watersheds contributing to Big Creek burned in 1988, 2000, 2005, 2006, 2007, and 2008. Forests in the area are predominantly Douglas-fir and ponderosa pine.

Parts of the Big Creek and Middle Fork Salmon River drainages burned in 2000 in the Diamond Peak Fire. From 2001 through 2004 the researchers sampled six tributaries to Big Creek having differing amounts and severity of fire. Pilliod’s crew compared these biotic and abiotic data to those of seven unburned watersheds of the South Fork Salmon River drainage. Stream-bottom insect communities in the burned and unburned watersheds did not differ pre-fire, in 1999 and 2000.

## ***Interaction of fire and flow is key***

More severe and widespread burns produced greater yearly variability in sediment loads, organic and large woody debris, and bank undercutting. The scientists found that an “interaction between fire and flow can result in decreased habitat stability in burned catchments.” They continued, “When fire burns in a mosaic across a landscape, streams within more extensively burned riparian forests (and upland forests by correlation) exhibit greater annual variation in mobile sediment loads, large woody debris, organic debris, and undercut bank morphology, rather than perennially elevated or depressed levels of these variables.” These findings support the team’s hypothesis that the interaction of fire and flow is more important than either burn severity or peak stream flow alone in explaining post-fire stream habitat conditions and stream-bottom insect community structure. A high peak of stream flow probably flushed out much of the sediment and debris in the more severely burned watersheds.



Riparian vegetation recovers fairly quickly after wildfires. The top photo was taken one year after and the bottom photo was taken four years after the Diamond Peak Fire. Credit: David Pilliod.

Pilliod’s team found significant differences in stream-bottom insect community composition depending on burn severity. The more severely burned was a stream’s

watershed, the more dynamic was the stream-bottom insect community, and this changeability continued through the study period. The researchers concluded that variability among stream-bottom insect communities is tied to changes in habitat structures—sediment loads, organic and large woody debris, and riparian cover—precipitated by wildfire and peak stream flows. The communities in these streams did not become more similar to those of unburned reference streams with time since the burn.

“Interactions among fire, flow, and stream habitat may increase inter-annual habitat variability,” says Pilliod, “driving macroinvertebrate communities into a state of dynamic equilibrium for a duration approaching the length of the historic fire return interval of the study area,” about 10–25 years. “This amounts to an important, persistent role for fire in upland and riparian forests in structuring aquatic macroinvertebrate community composition.”

***“Interactions among fire, flow, and stream habitat may increase inter-annual habitat variability”***

## **The great unknown: Prescribed fire and stream communities**

In the next phase of their study, Pilliod and his colleagues used the knowledge gained in the wildfire research described above to compare the effects on stream communities of low severity wildfire versus prescribed fire.

Forest managers need more information about the effects of prescribed fire on stream and riparian habitats and species so they can better evaluate potential impacts and benefits of fire management practices. Use of prescribed fire in riparian areas has been restricted because of concerns about effects on sensitive habitats and organisms. “We know that prescribed fires typically burn at very low severity because managers want to be able to control the burn,” Pilliod explains.

Scientists theorize that periodic prescribed fire may somewhat mimic a natural fire regime, promoting habitat diversity and sustaining fire-dependent species. But this theory is basically untested, especially in riparian forests. The lack of concrete testing of this theory stems from the difficulty of coordinating research with management activities and the assumption that prescribed and wildland fire produce similar effects.

Only two studies have examined the effects of prescribed fire on stream ecosystems, and neither was done in ponderosa pine and Douglas-fir forests of the northern Rocky Mountains or studied effects on amphibians or salmonids. “So,” says Pilliod, “it’s difficult to evaluate potential effects of fuel reduction management plans on species of concern,” such as chinook salmon (federally threatened and endangered), bull trout (federally threatened), and westslope cutthroat trout (Idaho species of concern). But each year, forest managers use prescribed fires over thousands of acres of these forests.

The Payette National Forest was the setting for the prescribed fire portion of this study—specifically, the

Salmon River Mountains near the confluence of the South Fork Salmon River and the East Fork of the South Fork Salmon River. Fire has been actively suppressed in this area since the 1940s. Starting in 2006, some wildfires were managed for resource benefits, including fuel reduction. The historic fire return interval was at least 7 years.



Researcher Robert Arkle, U.S. Geological Survey, working in the South Fork Salmon River drainage. Credit: Corbin Hodges.

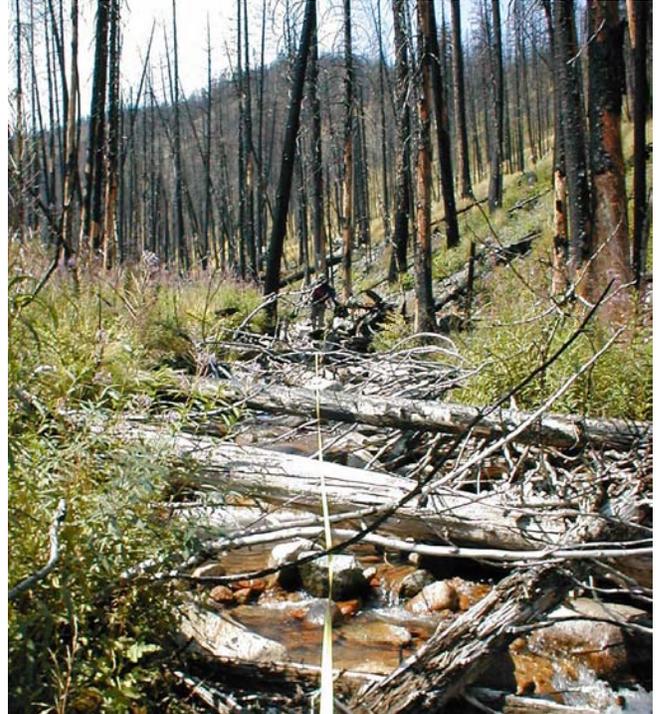
From 2001 to 2006, with funding from the U.S. Geological Survey, U.S.D.A. National Fire Plan, and Joint Fire Science Program, the researchers compared the effects of a prescribed fire and wildfires on stream ecosystems. “We studied the stream for 3 years before the prescribed fire was set so that we could understand the range of natural variation in the system prior to the fire,” says Pilliod, “and then studied it for 3 years after the prescribed fire. In reference streams nearby, we had before and after data for areas that weren’t burned over that same time period. So that allowed us to compare the prescribed fire stream to the neighboring reference streams to detect a response.”

The Parks-Eiguren prescribed burn was set on May 8, 2004. The project objective was to reduce small-diameter fuels while minimizing effects to soil, air, and water resources.



The Parks-Eiguren prescribed fire burned at low severity and burned little of the riparian vegetation along Parks Creek. Credit: David Pilliod.

Pilliod and his colleagues mapped burn severity of the prescribed fire using the same approach as the wildfire. They found that the prescribed fire burned 12 percent of the Parks Creek watershed, mostly in a low to mixed severity burn, and 3.8 percent of the riparian forest, all at low severity. They took stream habitat and community samples downstream of or within the prescribed fire area. They measured the amount of large woody debris, stream sediment depth, and water temperature; characterized the vegetation and degree of bank undercutting; analyzed water chemistry; sampled periphyton chlorophyll as an index of primary productivity; and collected and classified stream-bottom insects, amphibians, and fish.



Researchers sampled random locations along the stream for primary production, invertebrates, amphibians, and habitat. Credit: David Pilliod.

“We really took a whole system approach from primary production through primary consumers—macroinvertebrates—and secondary consumers—amphibians and fish,” notes Pilliod. “We tried to capture the range of the aquatic community.” Rocky Mountain tailed frogs and Idaho giant salamanders are the only two amphibians living in the stream. The frog tadpoles are grazers, so they feed directly on primary production. The adults of this species feed on insects. Sampling crews found trout in the prescribed fire stream.

### ***Effects of prescribed fire less than lowest intensity wildfire***

“We found no detectable change in the prescribed fire stream in the many different types of metrics we looked at,” Pilliod explains, “whether it was periphyton, macroinvertebrates, amphibians, fish, even water chemistry. We think that’s partly because the severity and extent of the

fire were so low in the riparian forest relative to wildfires, which is probably pretty typical of prescribed fires.” He notes that the burn was set in May, when fuels were moist.

“We found that the prescribed fire did not mimic the in-stream ecological effects of wildland fire,” says Pilliod, “even in watersheds with burn severities and extents similar to the prescribed fire.” He continues, “We found that even if a wildfire burns at a very low severity and extent in a watershed, you can still detect an effect in stream communities. So that suggests that our prescribed burning is even lower than the lowest wildfire. It’s off the radar.” Even in the unburned reference streams there were fairly wide natural fluctuations in several of the measures studied, so disturbances may have to be quite drastic to be detectable.

Pilliod and his colleagues summarized their findings this way in a recent journal article: “In contrast to the lack of effects following the Parks-Eiguren prescribed fire, [we found] that a nearby mixed-severity wildfire affected riparian and stream habitats and communities in comparable streams. Macroinvertebrate community composition was increasingly variable with increasing riparian burn severity for four years following wildfire. Tailed frog densities were lower in the wildfire burned catchments compared to unburned catchments. In-stream habitat components known to influence biotic communities dramatically increased (e.g., water temperature), decreased (e.g., riparian canopy cover), or exhibited increased inter-annual variability (e.g., sediment, large wood) for several years post-wildfire.” They continued, “The primary difference between [the] wildfire catchments and Parks Creek catchment was that in the wildfire burned catchments, the riparian forests along each stream burned proportionately to the amount [and severity] of upland vegetation burned. These differences could be critical since many of the in-stream habitat components affected by the wildfire are derived from the riparian forest.”

The researchers used data collected by Forest Service scientist Vicki Saab to compare the burn severity and patterns of the Parks-Eiguren prescribed fire to those of six other prescribed fires in ponderosa pine forests in the West and found them to be similar. Therefore, the lack of stream ecosystem effects found may be typical for prescribed burns in these forests where fire does not enter the riparian zone.

Managers often wish to exclude prescribed fire from riparian areas to prevent potentially negative effects on stream habitat for sensitive species. This study seems to confirm that forest managers can use prescribed fire in dry ponderosa pine forests to reduce understory fuel loads while maintaining pre-fire conditions within riparian forests and streams.

### **Many questions remain**

The door is wide open for further research on fire effects on stream communities and habitats. “It would be interesting to get a better understanding of how fire in the riparian zone vegetation plays a role in the ecology of the streams,” Pilliod notes. “I think we really do not understand

## **Management Implications**

- Spring prescribed fires burned when fuels are moist result in very low burn severity of riparian vegetation and a “prescribed fire regime” of this type could amount to fire exclusion in the riparian forest.
- Early season prescribed fires in central Idaho may not alter the living and dead riparian vegetation sufficiently to affect stream habitats or biotic communities.
- From a stream or riparian perspective, prescribed fires set under typical conditions might not act as ecological surrogates for wildfire in ponderosa pine forests in the Intermountain West.

that at all. Some national forests are starting to move in that direction because they see the importance of having some disturbance in riparian systems.”

Riparian areas in ponderosa pine forests have evolved with frequent mixed-severity patchy fires. “If forests are managed so that riparian areas are not allowed to burn,” says Pilliod, “we do not really know what the consequences are.” Long-term effects could be negative because some stream and riparian species are adapted to wildfire-induced habitat changes. Fires in the riparian zone probably increase the diversity of stream habitat by changing stream structure and primary production characteristics.

Pilliod’s team would also like to understand the degree to which the patterns noted here apply to other forest types. “The patterns we observed in these dry Intermountain West forests—are they similar to other forest types with other fire regimes, such as lodgepole pine forests or coastal or mesic forests?” asks Pilliod. Forthcoming results from this research team’s replicate testing in Montana and Oregon should begin to answer that question.

Pilliod would also like to see research into the effects of fuel reduction on stream ecosystems and communities receiving repeat treatments and different types and timing of treatments (e.g., broadcast burning; thinning and pile burning versus thinning and broadcast burning; burning in fall versus in spring).

## **Further Information: Publications and Web Resources**

- Arkle, Robert S., and David S. Pilliod. 2009. Prescribed fires as ecological surrogates for wildfires: A stream and riparian perspective. *Forest Ecology and Management*.
- Arkle, Robert S., David S. Pilliod, and Katherine Strickler. Fire, flow, and dynamic equilibrium in stream macroinvertebrate communities. in press. *Freshwater Biology*.

## Scientist Profiles

David S. Pilliod is a Research Ecologist with the U.S. Geological Survey Forest and Rangeland Ecosystem Science Center in Boise, ID.

David Pilliod can be reached at:  
U.S. Geological Survey  
970 Lusk St., Boise, ID 83706  
Phone: 208-426-5202  
Email: dpilliod@usgs.gov



R. Bruce Bury is a Research Zoologist with the U.S. Geological Survey Forest and Rangeland Ecosystem Science Center in Corvallis, OR.

Bruce Bury can be reached at:  
U.S. Geological Survey  
3200 SW Jefferson Way  
Corvallis, OR 97330  
Phone: 541-750-1010  
Email: buryb@usgs.gov



P. Stephen Corn is a Research Zoologist with the U.S. Geological Survey Northern Rocky Mountain Science Center, Aldo Leopold Wilderness Research Institute in Missoula, MT.

Steve Corn can be reached at:  
U.S. Geological Survey  
Aldo Leopold Wilderness Research Institute  
790 E. Beckwith Ave.  
Missoula, MT 59801  
Phone: 406-542-4191  
Email: steve\_corn@usgs.gov



Robert S. Arkle is an Ecologist with the U.S. Geological Survey Forest and Rangeland Ecosystem Science Center in Boise, ID.

Robert Arkle can be reached at:  
U.S. Geological Survey  
970 Lusk St., Boise, ID 83706  
Phone: 208-426-5205  
Email: rarkle@usgs.gov



## Collaborators

Katherine Strickler, Department of Fish and Wildlife Resources, University of Idaho, Moscow, ID

Victoria (Vicki) Saab, Forest Service Rocky Mountain Research Station, Bozeman, MT

*Results presented in JFSP Final Reports may not have been peer-reviewed and should be interpreted as tentative until published in a peer-reviewed source.*

**The information in this Brief is written from JFSP Project Number 01-1-3-12, which is available at [www.firescience.gov](http://www.firescience.gov).**

## An Interagency Research, Development, and Applications Partnership



JFSP *Fire Science Brief*  
is published monthly.  
Our goal is to help managers  
find and use the best available  
fire science information.

Learn more about the  
Joint Fire Science Program at  
[www.firescience.gov](http://www.firescience.gov)

John Cissel  
Program Manager  
208-387-5349  
National Interagency Fire Center  
3833 S. Development Ave.  
Boise, ID 83705-5354

Tim Swedberg  
Communication Director  
[Timothy\\_Swedberg@nifc.blm.gov](mailto:Timothy_Swedberg@nifc.blm.gov)  
208-387-5865

Writer  
Joy Drohan  
[jdrohan@nasw.org](mailto:jdrohan@nasw.org)

Design and Layout  
RED, Inc. Communications  
[red@redinc.com](mailto:red@redinc.com)  
208-528-0051

The mention of company names,  
trade names, or commercial products  
does not constitute endorsement  
or recommendation for use  
by the federal government.