

**Final Report to Joint Fire Science Program
JFSP Project Number 01-1-3-12**

Project Title: Effects of Fire on Stream Ecosystems in Western Forests

Project Location: Idaho: 2000 Diamond Peak Fire, Krassel RD-Payette NF; Montana: 2000 Bitterroot Valley Fire Complex, Sula RD-Bitterroot NF; Oregon: 2001 Quartz Fire, Applegate RD-Rogue NF; Grayback Mtn-Siskiyou NF; 2002 Biscuit Fire, Grants Pass Resource Area-Medford BLM.

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This final report is being submitted to the Joint Fire Science Program to provide a summary of findings, accomplished deliverables to date, and proposed products. This information is preliminary in nature and has not been peer-reviewed. Users are cautioned to consider carefully the provisional nature of the information. Final findings will be published in refereed publications (see list of deliverables enclosed). Details on the study background, objectives, methods, and annual reports are presented on our web page (<http://leopold.wilderness.net/research/fprojects/F003.htm>). This project was supported from the Joint Fire Science Program (65%), USFS R1/R4 National Fire Plan (22%), USGS Amphibian Research and Monitoring Initiative (10%), USGS Fire Science Program (3%), and Aldo Leopold Wilderness Research Institute (1%).

SUMMARY OF PRELIMINARY FINDINGS TO DATE

To better understand the effects of wildland fires on stream biota and habitat conditions, burn severity was estimated across entire watersheds and within riparian forests.

- Burn severity was defined as the effect of fire on post-fire vegetation measured from Landsat Enhanced Thematic Mapper (ETM+7) satellite imagery (30 m resolution) and post-fire field data. Using specific bands of wavelengths detected by the satellite sensor, we classified the tree burn severity in entire watersheds and in 20-m wide riparian buffers in the 2000 Diamond Peak Fire in Idaho, 2000 Bitterroot Valley Complex in Montana, and the 2001 Quartz Fire in Oregon. We ground truthed data and found that our classification scheme correctly identified unburned and low severity areas 59% of the time and mixed to high severity areas 95% of the time.
- Normalized Difference Vegetation Index (NDVI), Normalized Burn Ratio (NBR), and delta NBR (which compares pre-burn images to post-burn images) provided effective measures of burn severity that improved analyses of fire effects on stream biota.

Streams flowing through burned watersheds were warmer and contained more sediment.

- Elevated temperatures in 2nd-3rd order streams in Idaho persisted for 3 years post-fire and then returned to levels found in unburned streams. This cooling pattern correlated with the recovery of riparian vegetation. No major differences in stream temperatures were noted between burned and unburned watersheds in Montana or Oregon.
- Sediment levels were generally higher in streams flowing through burned watersheds, particularly high severity burns. Study streams in Idaho were the most influenced by sediment, probably due to the erosive Idaho batholith.

Water temperatures were more variable in watersheds with higher burn severity.

- Daily fluctuations in water temperature were greater in streams flowing through high severity burns than low severity burns. This was likely caused by loss of riparian canopy cover resulting in colder night temperatures (daily minimums) and higher day temperatures (daily maximums).

Amounts of instream large woody debris varied with riparian burn severity and annual peak flow.

- In Idaho streams, large woody debris (>5 cm diameter) was more abundant in streams flowing through high severity riparian burns over the four years post-fire.
- In contrast, low severity burns in the riparian forests were associated with greater annual changes in large woody debris. We suspect that low severity fires in the riparian forest resulted in delayed tree mortality which would have resulted in steady accumulations of dead wood in the streams over time, except that large woody debris was negatively related to annual peak flow. Therefore, higher flows removed large wood.

High flow events in spring runoff flushed sediment from streams.

- Inter-annual fluctuations in sediment load were greater in streams flowing through high severity burns than low severity burns.
- Changes in sediment levels were associated with peak flow. Sediment levels decreased in years with high peak flows (spring runoff), especially in watersheds with high severity fires where sediment levels were higher during years with below-average peak flow. The same pattern was observed for small organic debris (<5 cm diameter).

Macroinvertebrate community composition was influenced by burn extent of the watershed and sediment levels in streams.

- For 2-4 years after the Diamond Peak Fire Complex burned 606 km² of central Idaho, macroinvertebrate densities in high-gradient, low-order streams were higher in 6 burned watersheds compared to 7 unburned reference watersheds. The similar habitat conditions and macroinvertebrate communities in burned and reference streams before the fire (1998-1999) provided evidence that this difference was caused by the fire.
- Numbers of water-quality sensitive taxa (e.g., mayflies, stonesflies, and caddisflies) were more variable in watersheds that burned at high severity and over greater extent (>25% of the watershed). This variability appeared to be associated with shifts in habitat conditions, particularly fluctuations in sediment load. Multivariate analysis indicated that sediment levels and burn severity were the strongest predictors of macroinvertebrate community composition, except in 2003 when an above-normal peak flow event flushed sediment from the streams.
- It appears that the cumulative effects of habitat change decreased disturbance sensitive taxa in streams flowing burned watersheds, as seen in 2004. Two insect taxa, the caddisfly *Arctopsyche* and the stonefly *Doroneuria* were characteristic of streams with low burn extent (<25%) in all years.

Tailed frog reproduction was generally lower in streams flowing through burned watersheds.

- The density of tailed frog (*Ascaphus* spp.) tadpoles was lower in burned streams compared to unburned reference streams in Idaho and Oregon, but less so in Montana. This pattern varied annually and appeared to be somewhat influenced by peak flow events. For example, the only year that tailed frog tadpole densities were significantly lower in burned streams compared to unburned streams in Montana was in 2004, a year after the unusually high peak flow of 2003. This time delay is caused by their life history traits: eggs are deposited in mid-summer, hatching development is slow, and tadpoles grow slowly because they are largely inactive (e.g., buried into rocky substrate) until the following spring. Thus, a fire-induced hydrological disturbance in the summer of 2003 would not appear as a decline in tadpole captures until 2004.

Unburned riparian forests may reduce the effects of high severity wildland fires on tailed frogs.

- Using an information theoretic approach, we explored the influence of upland versus riparian burn severity on tailed frog tadpole density after accounting for known habitat associations. In particular, we hypothesized that the effects of riparian tree burn severity would be greater than the effects of upland tree burn severity on tailed frog tadpole densities. We discovered that the interaction of upland and riparian tree burn severity were the strongest predictors of tadpole densities after accounting for differences in substrate characteristics. This suggests that when a fire is hot enough to carry from the

uplands through the riparian forest, then effects on streams are major, whereas if riparian forests do not burn then streams are somewhat protected from the influence of fire.

Some patterns of biotic and abiotic responses to fire were fairly similar across geographic regions.

- Wildfires appeared to result in short-term (1-4 years post-fire) negative effects on tailed frog reproduction in most burned watersheds in the different geographic regions we examined. Tailed frogs appeared to be most sensitive to changes in increased stream temperatures and sedimentation, which fits our prior knowledge of these animals in areas subjected to timber harvest.
- Tailed frogs and macroinvertebrates responded similarly to perturbations associated with hydrological processes (i.e., high peak flow events in burned watersheds), which is arguably the primary factor influencing post-fire resistance and resilience of stream biota (Gresswell 1999).

Regression tree analyses showed regional differences in amphibian responses to fire.

Overall, geographic location was the most important predictor variable shaping regression tree models. Thus, we recommend that each region be analyzed as unique or different entities (i.e., fire effects in one region are not the same as another fire in the Pacific Northwest).

DELIVERABLES

<i>Proposed</i>	<i>Accomplished/Status</i>
Annual progress reports	Annual progress reports completed
Several journal articles	6 publications completed, 4 additional draft manuscripts to be submitted in 2007
	Refereed publications reviewing fire effects on amphibians: * Pilliod, D., R.B. Bury, E.J. Hyde, C.A. Pearl, and P.S. Corn. 2003. Fire and amphibians in North America. Special Issue: Fire and Aquatic Ecosystems. Forest Ecology and Management 178:163-181. * Bury, R.B. 2004. Wildfire, fuels reduction and herpetofaunas across complex landscape mosaics in western forests. Special Issue: Fire in the West. Conservation Biology 18:968-975.

Additional publications providing information to managers:

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Bury, R.B., D.J. Major, and D.S. Pilliod. 2002. Responses of Amphibians to Fire Disturbance in Pacific Northwest Forests: a Review. Pages 34-42 in *The role of fire in nongame wildlife management and community restoration: traditional uses and new directions*. Edited by W.M. Ford, K.R. Russell, and C.E. Moorman. General Technical Report NE-288. USDA Forest Service, Northeastern Research Station, Newtown Square, PA.

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Bury, R.B., D.S. Pilliod, E.J. Hyde, D. Ashton, M. Hayes and others. 2003. Sampling stream amphibians in the Pacific Northwest. CD Rom (Training module). Available from: Soc. Northwestern Vertebrate Biologists.

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Bury, R.B. 2004. Stream amphibians. Pp. 23-27. *In* Sarr, D.A., D.C. Odion, D.E. Hibbs, J. Weikel, R.E. Gresswell, R.B. Bury, N.M. Czarnomski, R. Pabst, J. Shatford, and A. Moldenke. 2005. *Riparian Zone Forest Management and the Protection of Biodiversity: A Problem Analysis*. Technical Bulletin No. 908. Research Triangle Park, N.C. National Center for Air and Stream Improvement (NCASI), Inc. 107 pp. plus appendices.

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Jain, T.B., D.S. Pilliod, and R.T. Graham. 2004. Tongue-tied. *Wildfire Magazine* July/August Issue:22-26.

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Jain, T.B., R.T. Graham, and D.S. Pilliod. 2006. The relation between forest structure and soil burn severity. Pages 615-631 in Andrews, P.L., and B.W. Butler (comps). *Fuels management—How to measure success*. Proceedings RMRS-P-41. USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Draft manuscripts completed

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Arkle, R.S., K. Strickler, and D.S. Pilliod. Ecological complexity of aquatic-terrestrial linkages: interactions of upland, riparian, and instream disturbances on macroinvertebrate communities. To be submitted to *Ecology*.

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Bury, R.B., D.S. Pilliod, S. Wessell, E. Hyde, D. DeGross, and P.S. Corn. Burned and unburned forest watersheds in the western U.S.: Responses of stream amphibians and associated habitats. To be submitted to *Forest Ecology and Management*.

	* Pilliod, D.S., R.B. Bury, P.S. Corn, J.S. Evans, and T.B. Jain. Effects of burn severity on stream amphibian reproduction in the Northwest, USA. To be submitted to Ecological Applications. * Jain, T.B., D.S. Pilliod, R.T. Graham, L. Lentile, J. Evans, N. Seavy, J. Alexander. <i>In prep.</i> A literature synthesis, evaluation, and validation of soil and tree burn severity. To be submitted to Ecological Applications.
Host 2 Workshops	Both workshops completed. * Stream Amphibians: Sampling, Ecology and Management. Society of Northwestern Vertebrate Biology, Humboldt State University, Arcata, California. March 2003. R.B. Bury, D.S. Pilliod, D. Ashton, Organizers. * Fire and Fuel Reduction Effects on Wildlife in the Northwest. Northwestern Scientific Association and Society for Northwestern Vertebrate Biology, Ellensburg, WA. 26 March 2004. D.S. Pilliod and R.B. Bury, Organizers.
Presentations	24 science presentations completed, 9 information exchanges performed with local managers and biologists, and 1 field trip conducted. Papers and posters presented at professional scientific meetings, symposia, and seminars * Pilliod, D.S., R.B. Bury, and P.S. Corn. 2002. Ecological Effects of Fire and Fuel Reduction Practices on Aquatic Amphibians in the United States. Paper presented at Fire and Aquatic Ecosystems Workshop, Rocky Mountain Research Station, Boise, ID, 22-24 April 2002. * Hyde, E.J., and R.B. Bury. 2003. Amphibian Responses to Fire in the Pacific Northwest. Paper presented at Northwest Section and Oregon Chapter, Wildlife Society. Eugene, Oregon. Feb. 2003. * Bury, R B. and E.J. Hyde. 2003. Amphibian Responses to Fire in the Pacific Northwest: Complex Answers to Simple Questions. Paper presented at Dept. Fisheries and Wildlife, Oregon State University, Corvallis. March 2003. * Pilliod, D.S., R.B. Bury, and P.S. Corn. 2003. Effects of prescribed and wildland fire on stream ecosystems in western forests. Paper presented at Joint Fire Sciences Program, Phoenix, AZ, 12 March 2003.

- * Gibson, J. and R.B. Bury. The Challenges of Managing for Fire and Species Diversity within the Wildland-urban Interface. Paper presented at Society for Northwestern Vertebrate Biologists, Humboldt State University, Arcata, California. March 2003.
- * Pilliod, D.S. and B.R. Hossack. 2003. Rapid assessment of stream amphibians. Paper presented at Sampling Stream Amphibians Workshop, Arcata, CA, 19 March 2003.
- * Pilliod, D.S. 2003. Changes in stream amphibian populations following large fires in Idaho. Paper presented at Society for Northwestern Vertebrate Biology, Arcata, CA, 20-21 March 2003.
- * Pilliod, D.S. 2003. Changes in stream amphibian populations following large fires. Paper presented at University of Montana Chapter of The Wildlife Society, Missoula, MT, 1 April 2003.
- * Pilliod, D.S. 2003. Effects of wildland fires on stream communities. Paper presented at Fire Lab Seminar Series, Rocky Mountain Research Station, Missoula, Montana, 23 October 2003.
- * Campbell, D.H., E. Muths, B.R. Hossack, D.S. Pilliod, E.J. Hyde, and P.S. Corn. 2003. Aquatic chemistry of amphibian breeding habitats in the mountains of western North America. Paper presented at Society for Environmental Toxicology and Contamination Meeting, Austin, Texas, 11-13 November 2003.
- * Bury, R B. and E.J. Hyde. 2003. Wildfire and Fuels Reduction in Northwest Forests: Responses of Amphibians and Reptiles. Paper presented at Fire Ecology and Resource Management Workshop, The Wildlife Society - Western Section. Arcata, California. Nov 2003.
- * Pilliod, D.S. 2003. Out of the caldron and into the fire: amphibian responses to wildfires in the Northern Rockies. Paper presented at University of Montana Ecology Seminar Series, Missoula, MT, 21 November 2003.
- * Campbell, D.H., E. Muths, B.R. Hossack, D.S. Pilliod, E.J. Hyde, and P.S. Corn. 2003. Aquatic chemistry of amphibian breeding habitats in the mountains of western North America. Paper presented at Society for Environmental Toxicology and Contamination Meeting, Austin, Texas, 11-13 November 2003.

- * Pilliod, D.S. 2003. Amphibians and Fire in the Rockies. University of Idaho Class Forestry 501 Fire, Water, and People, Moscow, ID, 1 December.
- * Bury, R.B., D.S. Pilliod, E.L. Bull. 2004. Fire and hazardous fuel reduction in the West: perspectives and challenges. Paper presented at Joint Meeting of the Society for Northwestern Vertebrate Biology and Northwestern Scientific Association, Ellensburg, WA, 26 March.
- * Pilliod, D.S., R.B. Bury, E.J. Hyde, and P.S. Corn. 2004. Effects of wildland fires on stream amphibian populations in the greater Northwest. Paper presented at Joint Meeting of the Society for Northwestern Vertebrate Biology and Northwestern Scientific Association, Ellensburg, WA, 26 March.
- * Pilliod, D.S., R.B. Bury, and P.S. Corn. 2004. Effects of prescribed and wildland fire on stream ecosystems in western forests. Paper presented at Joint Fire Sciences Program, Phoenix, AZ, March 2004.
- * Pilliod, D.S. 2005. Wildfire effects on stream communities in Idaho. Department of Biology seminar series, Boise State University, Boise, ID, 12 November.
- * Pilliod, D.S. 2005. How are forest-dwelling amphibians coping with the recent wildfires in the northern Rockies? Keynote address at Idaho Herpetological Society annual meeting, Boise, ID, 13 November.
- * Pilliod, D.S. 2005. Effects of burn severity on stream amphibian populations. Presentation at special session on Wildlife and Fire at joint meeting of Society for Northwestern Vertebrate Biology and Oregon Chapter The Wildlife Society, Corvallis, OR, 24 February.
- * Pilliod, D.S. R. Arkle, P.S. Corn, and R.B. Bury. 2005. Effects of prescribed and wildland fire on stream ecosystems in western forests. Poster presented at annual meeting Joint Fire Sciences Program, San Diego, CA, 1 November.
- * Jain, T.B., D.S. Pilliod, N. Seavy, R.A. Graham, and J. Alexander. 2006. A hierarchical classification of severity: A reevaluation of severity and implications toward management. Paper presented at the International Silviculture Workshop.

- * Pilliod, D.S., R. Arkle, R.B. Bury, T. Jain, and J. Evans. 2006. Fire in riparian forests: effects on stream amphibian reproduction in the Northwest, USA. International Society of Fire Ecology and Management, San Diego, CA, 7 November.
- * Arkle, R.S., D.S. Pilliod, and K. Strickler. 2006. Interactions between fire, flow, and sediment affect aquatic macroinvertebrates. International Society of Fire Ecology and Management, San Diego, CA, 7 November.

Information exchanges with local forest service and blm managers, and agency training workshops

- * Hyde, E.J., and R.B. Bury. 2002. Inventory and Monitoring Needs: Herpetofauna and Wildfire in the Klamath Province. Paper presented at National Park Service, Klamath Network Science Meeting, Ashland, Oregon. Nov 2002.
- * Bury, R B. and E.J. Hyde. 2003. Headwater Amphibians: Abundance, Tolerance Limits and Recovery Rates in Forests Subject to Timber Harvest and Wildfire. Poster presented at Oregon Headwaters Research Consortium, Corvallis, Oregon. Poster. Jan 2003.
- * Bury, R.B. 2003. *RAPP Session* (Research and Products/Projects on Wildlife and Fire Studies in the Pacific Northwest. Coordination Meeting, Oregon/Washington BLM State Office and USGS Research, Corvallis, Oregon. May 2003.
- * Pilliod, D.S. 2003. Effects of wildland fires on stream communities on the Payette National Forest. Paper presented to the fire managers and biologists at Payette National Forest, McCall, ID. 1 May 2003.
- * Pilliod, D.S., R.B. Bury, T. Jain, and P.S. Corn. 2005. Tailed frog responses to burn severity in the Bitterroot Mountains. Presentation to Regional Training Academy, US Forest Service Region 1, Missoula, MT, 24 March.
- * Pilliod, D.S., R.B. Bury, and P.S. Corn. 2005. Effects of wildland fire on stream ecosystems. Presentation to USFS Region 1 Watersheds, Wildlife, and Fisheries Resources Program, Missoula, MT, 9 July.
- * Bury, R.B. 2006. Southwest Oregon: Responses of Stream Amphibians to the Quartz and Biscuit Wildfires. Tri-Forest Ecosystem Management Workshop, Gold Beach, Oregon. 6 February.

	* Bury, R.B., S. Wessell, and D. Degross. 2006. Fire Effects on Terrestrial and Stream Amphibians in the Pacific Northwest. Southwest Oregon: Responses of Stream Amphibians to the Quartz and Biscuit Wildfires. Tri-Forest Ecosystem Management Workshop, Gold Beach, Oregon. 6 February. * Pilliod, D.S. 2006. Interactions of upland, riparian, and instream disturbances on stream biota. Interrelationships between fire, aquatic and terrestrial fauna, and conservation planning session, USFS Region 4 Integrated Resources Workshop, Ogden, UT, 28 February.
	Field trip provided to fire managers * "Restoring Ecosystems: Fire Ecology, Planning and Application in Western Oregon" Conference, Eugene, OR. Central Cascades Adaptive Management Area, Little River Adaptive Management Area, and the NW Oregon Ecology Group. Assisted with field trip to the Spring Fire, Umpqua National Forest, so. Oregon. Federal and State agencies. May 2002.
Website	Websites available http://leopold.wilderness.net/research/fprojects/F003.htm http://fresc.usgs.gov/products/fire/
Final Report	Final report completed.