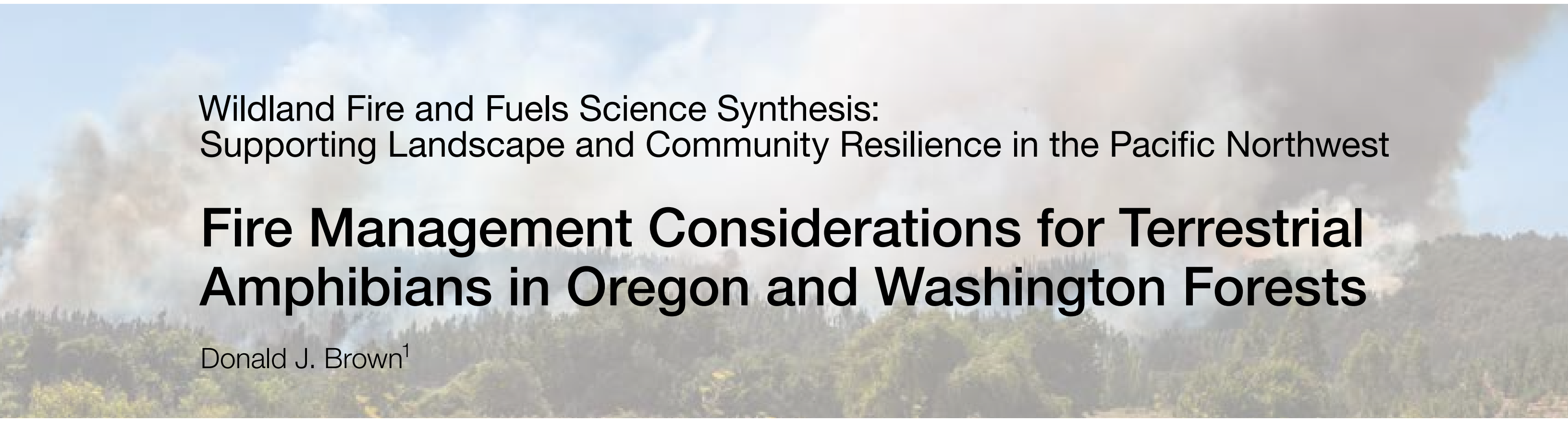
USDA Forest Service
U.S. DEPARTMENT OF AGRICULTURE

Pacific Northwest Research Station | General Technical Report PNW-GTR-1044 | July 2026



Wildland Fire and Fuels Science Synthesis:
Supporting Landscape and Community Resilience in the Pacific Northwest

Fire Management Considerations for Terrestrial Amphibians in Oregon and Washington Forests

Donald J. Brown[1]

Purpose

This synthesis reviews biological and ecological characteristics of amphibians that occur in upland forests of the Pacific Northwest, including fire and forestry studies that are relevant to fuel-reduction, active wildfire, and postfire management.

Introduction

Here I review biological and ecological characteristics of amphibians that are relevant to fuel-reduction treatments in upland forests, summarize the state of empirical knowledge regarding amphibian population responses to forest thinning and fire in the Pacific Northwest, and provide management considerations that balance fuel-reduction objectives with amphibian habitat needs. See Olson and Cousins (in press [in this series]) for amphibian considerations in aquatic and riparian environments. The scope of this review includes forested ecosystems in Oregon and Washington, with an emphasis on the west side of the Cascade Range crest where many at-risk terrestrial amphibians live. I consulted the primary literature on fire and forest management studies involving the terrestrial amphibian species found in the focal region, as well as broader synthesis papers for these topics. I provide species-specific information for the 23 focal amphibians included in this synthesis.

Amphibian Biology and Ecology

Amphibians are foundational members of forest ecosystems in the Pacific Northwest. They serve key functional roles as mid-trophic level predators and as prey for a wide range of vertebrates and invertebrates, contributing to forest nutrient cycling and the movement of energy between terrestrial and aquatic environments. They are ectothermic vertebrates with soft, permeable skin that allows water uptake and gas exchange. Their skin contains a layer of mucous and must remain moist. Amphibians live throughout the Pacific Northwest in streams and rivers, ponds and lakes, and riparian and upland environments. Life histories of individual species can be fully aquatic, semi-aquatic, fully terrestrial, or biphasic (aquatic and terrestrial in different life stages).

Amphibian distribution patterns are strongly tied to species-specific physiological requirements. Although some amphibians have adaptations that allow them to occupy relatively harsh environments, such as desert ecosystems, amphibian species richness at the global scale is highest in regions that are moist, warm, and forested (Buckley and Jetz 2007). This pattern results in particularly high species richness in the Pacific Northwest west of the Cascade Range crest. Some amphibian species are relatively prevalent throughout this portion of the Pacific Northwest, for example, the ensatina (*Ensatina eschscholtzii*), western red-backed salamander (*Plethodon vehiculum*), and Pacific treefrog

[1] **Donald J. Brown** is a research ecologist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 42218 NE Yale Bridge Road, Amboy, WA 98601.

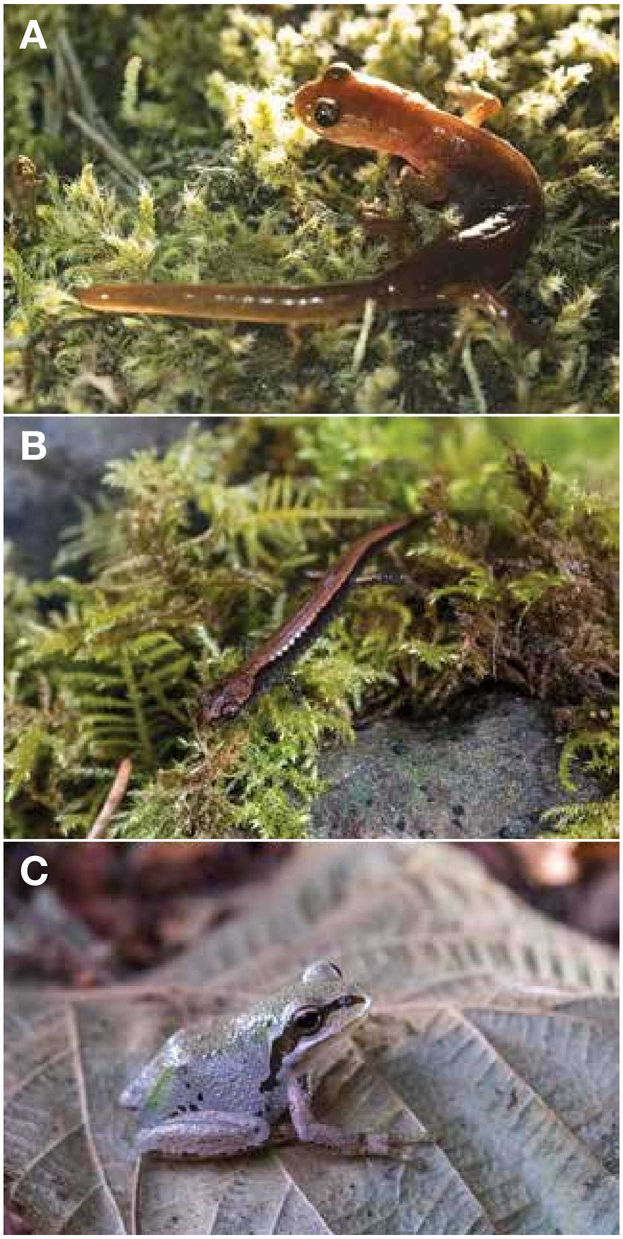


Figure 1—Examples of common forest amphibian species west of the Cascade Range crest in the Pacific Northwest: (a) ensatina (*Ensatina eschscholtzii*), (b) western red-backed salamander (*Plethodon vehiculum*), and (c) Pacific treefrog (*Pseudacris regilla*). Field studies indicate these species are less vulnerable to fuel-reduction treatments than amphibian species associated with late-successional and old-growth forest conditions. Photos by Donald J. Brown.

(*Pseudacris regilla*) (fig. 1), but most amphibian species have more restricted geographic distributions within the region.

Annual activity periods of amphibians are influenced by species physiology, life history characteristics, and local climates. For example, terrestrial salamanders in the family Plethodontidae are lungless and exchange gases entirely through their skin and a mucous membrane in the mouth and throat, making them particularly vulnerable to desiccation (Feder 1983). Terrestrial salamanders often exhibit a bimodal annual pattern that reflects suitability of the surface environment, with foraging and reproductive activity peaking in spring and fall when temperatures are moderate and rainfall is prevalent (e.g., Leclair et al. 2008, Peacock and Nussbaum 1973). Eleven fully terrestrial lungless salamanders occur in Oregon or Washington forests, all of which are endemic to the western United States, and six of which are designated as special status/sensitive species by a federal agency (USDI BLM and USDA FS 2022).

Amphibians are largely nocturnal, particularly when on land; this decreases the risk of desiccation and predation. In terrestrial environments, amphibians often occupy subsurface habitats during the day and nonactive periods (summer aestivation and overwintering). This can involve digging into the soil or inhabiting existing burrows, rock crevices, or large down wood. Amphibians respond to temporal changes in subsurface moisture and temperature by migrating vertically through the subsurface (Taub 1961). They forage at night when temperature and moisture conditions are suitable. Foraging activity generally occurs on the ground surface, but some species, such as the climbing salamanders of the plethodontid genus *Aneides,* routinely climb on trees and shrubs (McEntire 2016). When environmental conditions are suitable, they can remain under surface cover, such as moss, down wood, rocks, and leaf litter, during the day.

Space-use patterns are highly variable among amphibian species and are linked to their life history requirements. Some species migrate annually between terrestrial and aquatic habitats to reproduce. This is true for anurans (frogs and toads) and for mole salamanders (genus *Ambystoma*). These biphasic species typically remain within 300 m of breeding wetlands, although some species can travel more than 1 km between activity areas (Semlitsch and Bodie 2003). Alternatively, woodland salamanders (genus *Plethodon*) do not require aquatic habitats to reproduce, and they typically have very small home ranges. Empirical studies rarely document woodland salamanders moving farther than 10 m. For example, a capture-recapture study in Vancouver, British Columbia, documented a maximum relocation distance of 2.47 m for western red-backed salamanders

(Ovaska 1988). However, woodland salamanders are capable of dispersal movements, which enable individuals to respond to microhabitat quality degradation by making small shifts in space. To my knowledge, the longest recorded straight-line distance moved for a woodland salamander is 143 m (Sterrett et al. 2015).

Forest Habitat Relationships

Given their strict microclimate requirements, there have long been concerns about timber harvest (especially clearcutting) resulting in loss, degradation, and fragmentation of amphibian habitats. These concerns were elevated in the Pacific Northwest in the late 1980s and early 1990s (e.g., Blaustein et al. 1995), and many regional studies were conducted to better understand the influence of stand age on terrestrial amphibian occurrence and abundance (e.g., Bury et al. 1991, Raphael 1988, Welsh and Lind 1991). These studies revealed that many of the region's amphibians were associated with late-successional and old-growth (LSOG) forests. Of these, 18 were included in the Northwest Forest Plan (FEMAT 1993) (table 1).

For LSOG forest-associated amphibian species, silvicultural prescriptions and postharvest microhabitat characteristics can affect populations (see deMaynadier and Hunter 1995). Prescriptions that retain partial canopy cover are often less detrimental than clearcut harvesting because of the maintenance of comparatively cooler and moister microenvironments. For example, in the Willapa Hills of western Washington, Grialou et al. (2000) surveyed salamander communities, comparing ensatina and western red-backed salamander captures in stands that were clearcut or thinned in the previous 2–4 years to captures in control stands that were 45–60 years postharvest. They detected a strong negative effect of clearcut harvesting, but not thinning, on relative abundance of these terrestrial salamanders. Similarly, researchers did not detect an effect from forest thinning on terrestrial salamander captures in second-growth stands that were thinned in the previous 5–6 years in western Oregon; species-specific detections were primarily associated with distance from streams and the presence of down wood (Kluber et al. 2008, 2009).

Forest microhabitat characteristics have a strong influence on amphibian habitat quality and thus influence pre- and postharvest amphibian occurrence and density. For

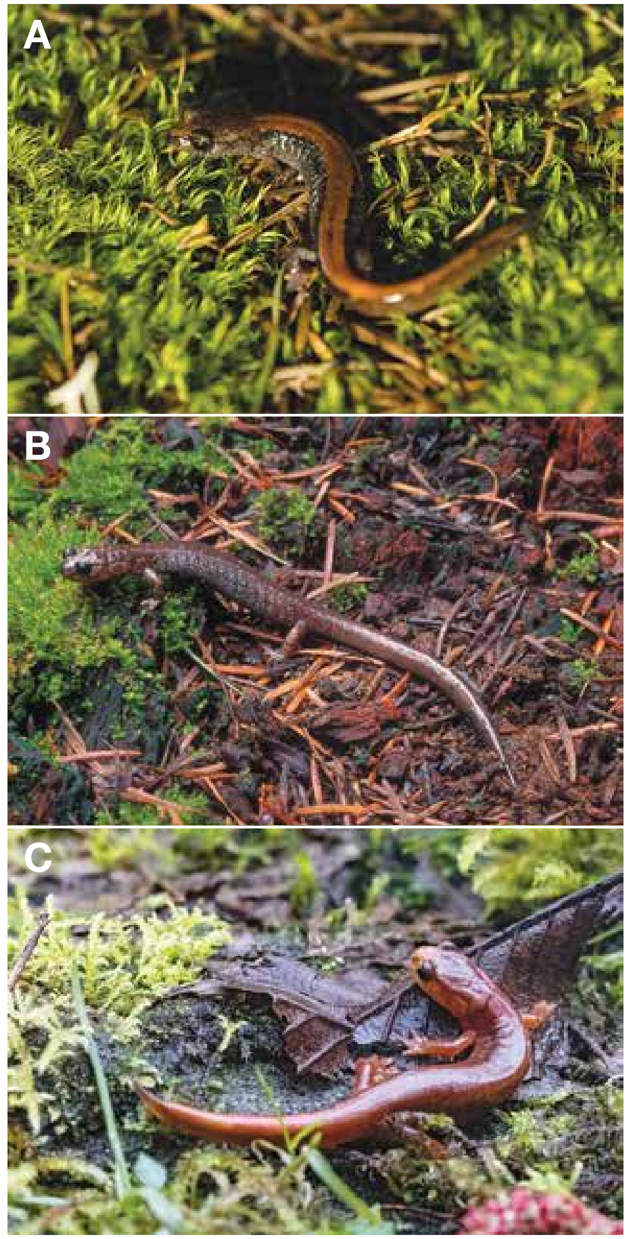


Figure 2—Examples of specialist forest amphibian species found west of the Cascade Range crest in the Pacific Northwest: (a) Larch Mountain salamander (*Plethodon larselli*), (b) Siskiyou Mountains salamander (*Plethodon stormi*), and (c) Van Dyke's salamander (*Plethodon vandykei*). These species have restricted geographic distributions and are associated with rocky substrates and late-successional forests; Van Dyke's salamanders are largely restricted to riparian zones adjacent to seeps and streams (see Olson and Cousins, in press [in this series]). Photos by Donald J. Brown (a, c) and William Leonard (b).

example, both Larch Mountain salamanders (*Plethodon larselli*) and Van Dyke's salamanders (*Plethodon vandykei*) are associated with rocky substrates (Jones et al. 2005) (fig. 2), but Van Dyke's salamanders also require high-moisture environments, which largely restricts their

Table 1—Summary of the natural history and fire and forest-management studies of native amphibian species that commonly use upland forest or other terrestrial environments in Oregon or Washington

Species	Sensitive species	Oregon/ Washington	Western/ Eastern	Terrestrial life stages	Terrestrial habitats	Distance from water	Fire studies	Forestry studies
Frogs and toads								
Anaxyrus boreas (western toad)	No	Yes/Yes	Yes/Yes	Juveniles/Adults	Closed forest, open forest, grassland, desert	<2500 m	Barrile et al. 2022, Bull 2006, Cook and Hayes 2020, Guscio et al. 2007, Hossack and Corn 2007, Hossack et al. 2009, Hossack et al. 2013a, Rochester et al. 2010, Vreeland and Tietje 2000	Karraker and Welsh 2006, McIntyre et al. 2025, Raphael 1988
Anaxyrus woodhousii (Woodhouse's toad)	Yes	Yes/Yes	No/Yes	Juveniles/Adults	Grassland, shrubland	<2000 m		
Ascaphus truei (coastal tailed frog)	No (NWFP)	Yes/Yes	Yes/No	Juveniles/Adults	Closed forest	<100 m		Bury 1983, Corn and Bury 1991, Karraker and Welsh 2006, Olson and Ares 2022, Olson and Burton 2014, Olson and Rugger 2007, Olson et al. 2014, Raphael 1988, Raphael et al. 2002, Rundio and Olson 2007
Lithobates pipiens (northern leopard frog)	Yes	Yes/Yes	No/Yes	Juveniles/Adults	Grassland, shrubland, open forest	<250 m		
Pseudacris regilla (Pacific treefrog)	No	Yes/Yes	Yes/Yes	Juveniles/Adults	Closed forest, open forest, grassland	<1500 m	Cook and Hayes 2020, Rochester et al. 2010, Vreeland and Tietje 2000	Bury 1983, Olson et al. 2014, Raphael 1988
Rana aurora (northern red-legged frog)	No	Yes/Yes	Yes/No	Juveniles/Adults	Closed forest	<300 m	Cole et al. 1997	Corn and Bury 1991, Olson and Ares 2022, Olson and Burton 2014, Olson et al. 2014
Spea intermontana (Great Basin spadefoot)	No	Yes/Yes	No/Yes	Juveniles/Adults	Grassland, shrubland, open forest	<350 m		
Salamanders								
Ambystoma gracile (northwestern salamander)	No (NWFP)	Yes/Yes	Yes/No	Juveniles/Adults	Closed forest, open forest	<1000 m		Corn and Bury 1991, Grialou et al. 2000, Olson and Burton 2014, Olson et al. 2014, Raphael 1988, Rundio and Olson 2007
Ambystoma macrodactylum (long-toed salamander)	No	Yes/Yes	Yes/Yes	Juveniles/Adults	Grassland, shrubland, open forest	<600 m (Stemle 2024)	Hossack and Corn 2007, Hossack et al. 2013a, 2013b	Naughton et al. 2000, McIntyre et al. 2025
Ambystoma tigrinum (eastern tiger salamander)	No	Yes/Yes	No/Yes	Juveniles/Adults	Grassland, shrubland, open forest, desert	<250 m		
Aneides ferreus (clouded salamander)	No (NWFP)	Yes/No	Yes/No	All	Closed forest, open forest, talus	N/A	Chelgren et al. 2011, Stephens 2023	Bury 1983, Corn and Bury 1991, Olson and Burton 2014, Olson et al. 2014, Raphael 1988
Aneides flavipunctatus/ klamathensis (black salamanders)[a]	Yes (NWFP)	Yes/No	Yes/No	All	Closed forest, open forest, talus	N/A		Raphael 1988

Table 1—Summary of the natural history and fire and forest-management studies of native amphibian species that commonly use upland forest or other terrestrial environments in Oregon or Washington (continued)

Species	Sensitive species	Oregon/ Washington	Western/ Eastern	Terrestrial life stages	Terrestrial habitats	Distance from water	Fire studies	Forestry studies
Batrachoseps attenuatus (California slender salamander)	No	Yes/No	Yes/No	All	Grassland, shrubland, open forest, closed forest	N/A		Bury 1983
Batrachoseps wrighti (Oregon slender salamander)	No (NWFP)	Yes/No	Yes/No	All	Closed forest, talus	N/A	Chelgren et al. 2011, Stephens 2023	Olson and Burton 2014, Olson et al. 2014, Rundio and Olson 2007
Dicamptodon copei/ tenebrosus (giant salamanders)	Yes (*copei*); No (*tenebrosus*) (NWFP)	Yes/Yes	Yes/No	Adults (non-paedomorphic)	Closed forest	<50 m (McComb et al. 1993)	Cole et al. 1997	Corn and Bury 1991, Grialou et al. 2000, Johnston 1994, Karraker and Welsh 2006, Olson and Ares 2022, Olson and Burton 2014, Olson and Rugger 2007, Olson et al. 2014, Raphael 1988, Raphael et al. 2002, Rundio and Olson 2007
Ensatina eschscholtzii (ensatina)[b]	No	Yes/Yes	Yes/No	All	Closed forest, open forest, talus	N/A	Chelgren et al. 2011, Cole et al. 1997, Rochester et al. 2010, Stephens 2023, Vreeland and Tietje 2000	Bury 1983, Corn and Bury 1991, Grialou et al. 2000, Karraker and Welsh 2006, Kluber et al. 2008, Olson and Ares 2022, Olson and Burton 2014, Olson and Kluber 2014, Olson et al. 2006, Olson et al. 2014, Raphael 1988, Raphael et al. 2002, Rundio and Olson 2007
Plethodon elongatus (Del Norte salamander)	No (NWFP)	Yes/No	Yes/No	All	Closed forest, talus	N/A	Major 2005	Diller and Wallace 1994, Karraker and Welsh 2006, Raphael 1988
Plethodon larselli (Larch Mountain salamander)	Yes (NWFP)	Yes/Yes	Yes/No	All	Closed forest, open forest, talus	N/A		
Plethodon stormi (Siskiyou Mountains salamander)	Yes (NWFP)	Yes/No	Yes/No	All	Closed forest, open forest, talus	N/A		
Plethodon vehiculum (western red-backed salamander)	No	Yes/Yes	Yes/No	All	Closed forest, open forest, talus	N/A	Chelgren et al. 2011, Cole et al. 1997, Stephens 2023	Corn and Bury 1991, Grialou et al. 2000, Kluber et al. 2008, Olson and Burton 2014, Olson and Kluber 2014, Olson and Rugger 2007, Olson et al. 2014, Raphael et al. 2002, Rundio and Olson 2007, Wilk et al. 2014
Taricha granulosa (rough-skinned newt)	No (NWFP)	Yes/Yes	Yes/No	Juveniles/Adults	Closed forest, open forest, grasslands	<400 m	Cole et al. 1997, Cook and Hayes 2020	Corn and Bury 1991, Grialou et al. 2000, Karraker and Welsh 2006, Olson and Ares 2022, Olson and Burton 2014, Olson and Rugger 2007, Olson et al. 2014, Raphael 1988, Rundio and Olson 2007

Note: Occurrences of species are indicated for the western and eastern sides of the Cascade Range crest. Sensitive species include species listed as sensitive by the Forest Service, Pacific Northwest Region regional forester or the state director of Oregon or Washington as of 2021; species included in the Northwest Forest Plan (NWFP) are noted (FEMAT 1993). The table is restricted to species that often occur >30 m from water in one or more life stages, excluding long-distance dispersal movements. Except where noted, geographic distribution and natural history information was derived from species reviews by Dodd (2023) for frogs and toads, Petranka (1988) for salamanders, and regional amphibian field guides (Corkran and Thoms 2006, Jones et al. 2005). Distance from water refers to the distance from waterbodies where terrestrial activity of aquatic-breeding amphibians is prevalent, it does not represent the maximum observed distance from water. Fire studies and forestry studies provide references to studies that included sampling data or inferred effects on species in terrestrial environments.

N/A = species do not reproduce in aquatic habitats.

[a] The species found in Oregon was historically referred to as *Aneides flavipunctatus* (black salamander) but was changed to *Aneides klamathensis* (Klamath black salamander) by Reilly and Wake (2019).

[b] The subspecies found in Oregon and Washington is *Ensatina eschscholtzii oregonensis* (Oregon ensatina).

Source for species names: Nicholson (2025).

local distributions to riparian zones adjacent to seeps and streams (McIntyre et al. 2006; see Olson and Cousins, in press [in this series] for additional information on Van Dyke's salamanders). Many habitat characteristics that are important for individual species are intrinsic to the location, such as elevation and aspect (which influence temperature and precipitation), slope, and soil type. Other important habitat characteristics can be directly influenced by management actions, regardless of location. This is particularly true of live and dead vegetation structure and complexity.

Many studies in the Pacific Northwest have focused on the influence of large down wood on amphibian habitat. In managed forests in the Oregon Cascade Range, Butts and McComb (2000) found strong positive relationships between ensatina captures and the volume of large down wood, and between ensatina presence and percentage of cover of logs >50-cm in diameter. Biek et al. (2002) noted that the clearcut sites had substantial large down wood (2000–3000 logs/ha) and hypothesized that retaining extensive large down wood reduced habitat degradation from loss of canopy cover. Other regional studies have provided additional support for this hypothesis (e.g., Aubry et al. 1988, Corn and Bury 1991, Kroll et al. 2015, Maguire et al. 2005, Raphael 1988).

Subcanopy live vegetation can directly affect microhabitat quality by influencing moisture dynamics and structural features that are used for cover and foraging, and indirectly by influencing invertebrate prey availability (Burrow and Maerz 2022). For example, Kluber et al. (2008) found that moss cover was an important microhabitat component for ensatina in the western hemlock (*Tsuga heterophylla*) vegetation zone of the Oregon Coast Range. Furthermore, Butts and McComb (2000) found that ensatina captures were positively associated with the percentage of fern cover and speculated that the relationship was a proxy for a positive association with the percentage of understory vegetation cover in general. Positive associations between understory vegetation cover and occurrence or abundance of amphibian species in upland forests have also been documented for several other species in the Pacific Northwest, including rough-skinned newt (*Taricha granulosa*), Larch Mountain salamander, and western red-backed salamander (Crisafulli et al. 2008, Maguire et al. 2005).

Research Gaps

- Few empirical studies have been conducted on upland amphibian responses to fire in the Pacific Northwest, limiting knowledge of species-specific responses and fire severity effects.
- Long-term empirical studies of upland amphibian responses to fuel reduction treatments are lacking in the Pacific Northwest, limiting the ability to predict expected population recovery times.

Responses to Fire

Relatively few studies have assessed terrestrial amphibian responses to fire across North America (see Anjos et al. 2021, Hossack and Pilliod 2011, Pilliod et al. 2003, Russell et al. 1999). Individual studies have reported negative, positive, or undetectable responses across different amphibian species, environments, and fire severities. Some studies suggest that fire does not typically result in substantial direct mortality (Brown et al. 2014a, Pilliod et al. 2003), but changes to important habitat conditions, such as overstory canopy cover and the presence of large down wood, can be strongly influenced by fire severity (e.g., Brown et al. 2014b, Halofsky et al. 2011). Although studies may report short-term negative impacts, the use of prescribed fire management in fire-suppressed forests is expected to have long-term benefits for many amphibian species (Pilliod et al. 2003, Russell et al. 1999).

Only a few studies have assessed upland amphibian responses to fire in the Pacific Northwest. Chelgren et al. (2011) used a control-impact approach to assess postfire responses of five terrestrial salamander species approximately 2 years after a wildfire in a mature Douglas-fir (*Pseudotsuga menziesii*)/western hemlock forest in western Oregon. They estimated that occupancy probability was lower in burned plots than control plots for all five species, but the fire effect was weak relative to the influences of topographic position and elevation. Stephens (2023) used a control-impact approach to assess ensatina responses to high-severity wildfires in mature coniferous forests in three regions of western Oregon, with recent (4–8 years postburn) and older (19–34 years postburn) wildfires included in the study. They estimated that plot occupancy and abundance was higher in unburned plots than in recently burned and older burned plots, and that plot occupancy and abundance were positively associated with the amount of large down wood. Similarly, a fire-response study in California that focused on the Del Norte salamander (*Plethodon elongatus*) also found that occupancy probability in burned plots was positively correlated with the amount of large down wood (Major 2005). In addition, Major (2005) reported that the density of large down wood was negatively correlated with fire severity. Collectively, these studies suggest that high-severity wildfires often reduce terrestrial habitat quality for amphibians in the Pacific Northwest, with measurable impacts to populations.

Management Considerations

Creation of firebreaks and roads can result in direct amphibian mortality and long-term habitat degradation; postfire restoration actions such as revegetation can reduce these impacts (see Pilliod et al. 2003).

Given their highly permeable skin, the use of fire retardants is also of concern for toxicity to amphibians (e.g., Lanctôt et al. 2024, Ozeri et al. 2021). The final environmental impact statement for the nationwide aerial application of fire retardant on national forest system land (USDA FS 2011) recommends not using fire retardant in critical habitat areas for sensitive amphibian species and prohibits use of fire retardants in critical habitat areas in national forests for some species that are federally listed under the Endangered Species Act (ESA 1973). Furthermore, concentrating use of fire retardants on ridgelines can maximize protection of watersheds while limiting the species directly impacted by the chemicals (USDA FS 2011: app. O).

Although experimental investigations of upland amphibian responses to postfire salvage logging are lacking, Pilliod et al. (2003) speculated that salvage logging may be more detrimental to amphibians than nonfire timber harvest because of greater soil disturbance. The fire and forestry studies reviewed here also suggest that as burned forests regenerate, large down wood maintains microhabitat conditions that support persistence of LSOG-associated amphibians in suboptimal burned habitats.

Because of their low dispersal rates, if terrestrial amphibian populations are extirpated in managed forest stands, it can take decades to centuries for recolonization. Balancing fuel-reduction needs with maintenance of important microhabitat features will promote persistence-in-place for affected amphibian populations (Thurman et al. 2020), thus benefitting long-term ecosystem health. When forest thinning is required for fire risk reduction, retaining partial overstory canopy and large down wood have been shown to reduce negative impacts of timber harvest on amphibians (e.g., Cafferata Coe et al. 2021, Clayton et al. 2009, McIntyre et al. 2025, Pilliod and Wind 2008). Given the benefits of retaining down wood, fine fuels, and understory vegetation, salvage logging and mastication treatments that hinder this could severely degrade habitat for amphibians in upland forests.

Conservation assessments and strategies focused on forest-associated amphibian species of concern in the Pacific Northwest promote a management strategy focused on habitat preservation. These focal species are typically habitat specialists with restricted local

Key Takeaways

- Amphibians are a foundational component of healthy forest ecosystems in the Pacific Northwest, playing key ecological roles for food webs and energy transfer among water, land, and air.
- For amphibian species that are associated with late-successional and old-growth forest conditions, fuel-reduction treatments can result in habitat degradation with measurable negative effects. These effects can be ameliorated by retaining canopy cover and large down wood and by reducing the use of large equipment, which compresses soil in amphibian habitats.
- During wildfires, keeping fire-retardant use and fire-break construction away from critical amphibian habitats can minimize effects on dispersal-limited and federal agency special status/sensitive species.
- After wildfire, retaining existing trees and large down wood can provide cool, moist microclimate conditions and microhabitat refugia for terrestrial amphibians.

distributions, therefore management limitations in high-quality habitat areas do not prevent the application of fuel reduction treatments across the surrounding landscape. For example, the conservation strategy for Siskiyou Mountains salamanders (*Plethodon stormi*) and Scott Bar salamanders (*Plethodon asupak*) in the Klamath National Forest recommended that fuel-reduction treatments focus on nonhabitat and low-quality habitat areas (Cuenca and Jones 2023). If fuel-reduction treatments are necessary in occupied, high-quality habitat patches, they recommend following specific guidelines that minimize habitat degradation, such as retaining an average of 70 percent canopy cover in the highest quality habitat areas and restricting prescribed burning to nonactive periods (i.e., summer aestivation and overwintering). Species-specific guidance documents are available for regional species of concern through the Interagency Special Status/Sensitive Species Program (https://www.fs.usda.gov/r6/isssp/), such as for the Siskiyou Mountains salamanders in Oregon (Olson et al. 2007: app. 4), Larch Mountain salamanders (Crisafulli et al. 2008), and Oregon slender salamanders (*Batrachoseps wrighti*) (Clayton and Olson 2009).

U.S. Standard Equivalents

When you know:	Multiply by:	To find:
Centimeters (cm)	0.394	Inches
Meters (m)	3.28	Feet
Kilometers (km)	0.621	Miles
Hectares (ha)	2.47	Acres

Suggested Citation

Brown, D. 2026. Fire management considerations for terrestrial amphibians in Oregon and Washington forests. In: Wright, V.; Keville, M., tech eds. Wildland fire and fuels science synthesis: supporting landscape and community resilience in the Pacific Northwest. Gen. Tech. Rep. PNW-GTR-1044. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

References

Anjos, A.G.; Solé, M.; Benchimol, M. 2021. Fire effects on anurans: what we know so far? Forest Ecology and Management. 495: 119338. https://doi.org/10.1016/j.foreco.2021.119338.

Aubry, K.B.; Jones, L.L.C.; Hall, P.A. 1988. Use of woody debris by plethodontid salamanders in Douglas-fir forests in Washington. In: Szaro, R.C.; Severson, K.E.; Patton, D.R., tech. coords. Management of amphibians, reptiles, and small mammals in North America. Proceedings of the symposium, July 19–21, 1988, Flagstaff, Arizona. Gen. Tech. Rep. RM-166. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 32–37. https://doi.org/10.2737/RM-GTR-166.

Barrile, G.M.; Chalfoun, A.D.; Estes-Zumpf, W.A.; Walters, A.K. 2022. Wildfire influences individual growth and breeding dispersal, but not survival and recruitment in a montane amphibian. Ecosphere. 13(8): e4212. https://doi.org/10.1002/ecs2.4212.

Biek, R.; Mills, L.S.; Bury, R.B. 2002. Terrestrial and stream amphibians across clearcut-forest interfaces in the Siskiyou Mountains, Oregon. Northwest Science. 76(2): 129–140.

Blaustein, A.P.; Beatty, J.J.; Olson, D.H.; Storm, R.M. 1995. The biology of amphibians and reptiles in old-growth forests in the Pacific Northwest. Gen. Tech. Rep. PNW-GTR-337. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 98 p. https://doi.org/10.2737/PNW-GTR-337.

Brown, D.J.; Duarte, A.; Mali, I.; Jones, M.C.; Forstner, M.R.J. 2014a. Potential impacts of a high severity wildfire on abundance, movement, and diversity of herpetofauna in the Lost Pines ecoregion of Texas. Herpetological Conservation and Biology. 9(1): 192–205. https://www.herpconbio.org/Volume_9/Issue_1/Brown_etal_2014.pdf.

Brown, D.J.; Nowlin, W.H.; Ozel, E.; Mali, I.; Episcopo, D.; Jones, M.C.; Forstner, M.R.J. 2014b. Comparison of short term low, moderate, and high severity fire impacts to aquatic and terrestrial ecosystem components of a southern USA mixed pine/hardwood forest. Forest Ecology and Management. 312: 179–192. https://doi.org/10.1016/j.foreco.2013.10.006.

Buckley, L.B.; Jetz, W. 2007. Environmental and historical constraints on global patterns of amphibian richness. Proceedings of the Royal Society B: Biological Sciences. 274(1614): 1167–1173. https://doi.org/10.1098/rspb.2006.0436.

Bull, E.L. 2006. Sexual differences in the ecology and habitat selection of western toads (*Bufo boreas*) in northeastern Oregon. Herpetological Conservation and Biology. 1(1): 27–38. https://research.fs.usda.gov/treesearch/27199. (December 30, 2025).

Burrow, A.; Maerz, J. 2022. How plants affect amphibian populations. Biological Reviews. 97(5): 1749–1767. https://doi.org/10.1111/brv.12861.

Bury, R.B. 1983. Differences in amphibian populations in logged and old growth redwood forest. Northwest Science. 57: 167–178.

Bury, R.B.; Corn, P.S.; Aubry, K.B. 1991. Regional patterns of terrestrial amphibian communities in Oregon and Washington. In: Ruggiero, L.F.; Aubry, K.B.; Carey, A.B.; Huff, M.H., tech. coords. Wildlife and vegetation of unmanaged Douglas-fir forests. Gen. Tech. Rep. PNW-GTR-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 341–350.

Butts, S.R.; McComb, W.C. 2000. Associations of forest-floor vertebrates with coarse woody debris in managed forests of western Oregon. Journal of Wildlife Management. 64(1): 95–104. https://doi.org/10.2307/3802978.

Cafferata Coe, F.; Garcia, T.; Olson, D.; Woodward, J. 2021. Wildlife in managed forests: forest amphibians. Portland, OR: Oregon Forest Resources Institute. https://oregonforests.org/publication-library/wildlife-managed-forests-forest-amphibians. (December 30, 2025).

Chelgren, N.D.; Adams, M.J.; Bailey, L.L.; Bury, R.B. 2011. Using multilevel spatial models to understand salamander site occupancy patterns after wildfire. Ecology. 92(2): 408–421. https://doi.org/10.1890/10-0322.1.

Clayton, D.R.; Olson, D.H. 2009. Conservation assessment for the Oregon slender salamander (*Batrachoseps wrighti*). Version 2.0. U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; U.S. Department of the Interior, Bureau of Land Management. 76 p. https://andrewsforest.oregonstate.edu/publications/4518.

Clayton, D.; Olson, D.H.; Nauman, R.S.; Reilly, E.C. 2009. Managing for the Siskiyou Mountains salamander (*Plethodon stormi*) in fuel treatment areas around at-risk communities. In: Olson, D.H.; Clayton, D.; R.S. Nauman, R.S.; Welsh, H.H., Jr., eds. Conservation of the Siskiyou Mountains Salamander (*Plethodon stormi*). Northwest Fauna 6. Olympia, WA: Society for Northwestern Vertebrate Biology: 39–42. Chapter 5.

Cole, E.C.; McComb, W.C.; Newton, M.; Chambers, C.L.; Leeming, J.P. 1997. Response of amphibians to clearcutting, burning, and glyphosate application in the Oregon Coast Range. Journal of Wildlife Management. 61(3): 656–664. https://doi.org/10.2307/3802173.

Cook, D.G.; Hayes, M.P. 2020. Post-fire species composition and abundance of a lentic-breeding amphibian assemblage: case study of Ledson Marsh. California Fish and Wildlife, Fire Special Issue: 110–128. http://dx.doi.org/10.51492/cfwj.firesi.8. (December 30, 2025).

Corkran, C.C.; Thoms, C.R. 2006. Amphibians of Oregon, Washington and British Columbia. Auburn, WA: Lone Pine Publishing. 176 p.

Corn, P.S.; Bury, R.B. 1991. Terrestrial amphibian communities in the Oregon Coast Range. In: Ruggiero, L.F.; Aubry, K.B.; Carey, A.B.; Huff, M.H., tech. eds. Wildlife and vegetation of unmanaged Douglas-fir forests. Gen. Tech. Rep. PNW-GTR-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 305–317.

Crisafulli, C.M.; Clayton, D.R.; Olson, D.H. 2008. Conservation assessment for the Larch Mountain salamander (*Plethodon larselli*). Version 1.0. U.S. Department of Agriculture, Forest Service, Region 6, and U.S. Department of the Interior, Bureau of Land Management, Interagency Special Status and Sensitive Species Program. 36 p. https://andrewsforest.oregonstate.edu/sites/default/files/lter/pubs/pdf/pub4516.pdf. (December 30, 2025).

Cuenca, S.; Jones, J. 2023. Siskiyou Mountains and Scott Bar salamander conservation strategy on land administered by the Klamath National Forest. Yreka, CA: U.S. Department of Agriculture, Forest Service, Klamath National Forest. 42 p.

deMaynadier, P.G.; Hunter, M.L., Jr. 1995. The relationship between forest management and amphibian ecology: a review of the North American literature. Environmental Reviews. 3(3–4): 230–261. https://doi.org/10.1139/a95-012.

Diller, L.V.; Wallace, R.L. 1994. Distribution and habitat of *Plethodon elongatus* on managed, young growth forests in north coastal California. Journal of Herpetology 28(3): 310–318. https://doi.org/10.2307/1564529.

Dodd, C.K., Jr. 2023. Frogs of the United States and Canada. 2nd ed. Baltimore: Johns Hopkins University Press. 954 p.

Endangered Species Act of 1973 [ESA]; 16 U.S.C. 1531–1536, 1538–1540.

Feder, M.E. 1983. Integrating the ecology and physiology of plethodontid salamanders. Herpetologica. 39(3): 291–310. https://www.jstor.org/stable/3892572.

Forest Ecosystem Management Assessment Team [FEMAT]. 1993. Forest ecosystem management: an ecological, economic, and social assessment. Portland, OR: U.S. Department of Agriculture; U.S. Department of the Interior [and others]. [Irregular pagination]. https://www.fs.usda.gov/r6/reo/library/downloads/documents/FEMAT-1993-Report.pdf. (February 14, 2025).

Grialou, J.A.; West, S.D.; Wilkins, R.N. 2000. The effects of forest clearcut harvesting and thinning on terrestrial salamanders. Journal of Wildlife Management. 64(1): 105–113. https://doi.org/10.2307/3802979.

Guscio, C.G.; Hossack, B.R.; Eby, L.A.; Corn, P.S. 2007. Post-breeding habitat use by adult boreal toads (*Bufo boreas*) after wildfire in Glacier National Park, USA. Herpetological Conservation and Biology. 3(1): 55–62. https://research.fs.usda.gov/treesearch/30874. (December 30, 2025).

Halofsky, J.E.; Donato, D.C.; Hibbs, D.E.; Campbell, J.L.; Cannon, M.D.; Fontaine, J.B.; Thompson, J.R.; Anthony, R.G.; Bormann, B.T.; Kayes, L.J.; Law, B.E.; Peterson, D.L.; Spies, T.A. 2011. Mixed-severity fire regimes: lessons and hypotheses from the Klamath-Siskiyou ecoregion. Ecosphere. 2(4): 40. https://doi.org/10.1890/ES10-00184.1.

Hossack, B.R.; Corn, P.S. 2007. Responses of pond-breeding amphibians to wildfire: short-term patterns in occupancy and colonization. Ecological Applications. 17(5): 1403–1410. https://doi.org/10.1890/06-2037.1.

Hossack, B.R.; Eby, L.A.; Guscio, C.G.; Corn, P.S. 2009. Thermal characteristics of amphibian microhabitats in a fire-disturbed landscape. Forest Ecology and Management. 258(7): 1414–1421. https://doi.org/10.1016/j.foreco.2009.06.043.

Hossack, B.R.; Lowe, W.H.; Corn, P.S. 2013a. Rapid increases and time-lagged declines in amphibian occupancy after wildfire. Conservation Biology. 27(1): 219–228. https://doi.org/10.1111/j.1523-1739.2012.01921.x.

Hossack, B.R.; Lowe, W.H.; Honeycutt, R.K.; Parks, S.A.; Corn, P.S. 2013b. Interactive effects of wildfire, forest management, and isolation on amphibian and parasite abundance. Ecological Applications. 23(2): 479–492. https://doi.org/10.1890/12-0316.1.

Hossack, B.R.; Pilliod, D.S. 2011. Amphibian responses to wildfire in the western United States: emerging patterns from short-term studies. Fire Ecology. 7(2): 129–144. https://fireecology.springeropen.com/articles/10.4996/fireecology.0702129.

Johnston, B. 1994. Terrestrial Pacific giant salamanders (*Dicamptodon tenebrosus* Good)— natural history and their response to forest practices. Vancouver, BC: University of British Columbia. 98 p. M.S. thesis.

Jones, L.L.C.; Leonard, W.P.; Olson, D.H. 2005. Amphibians of the Pacific Northwest. Seattle: Seattle Audubon Society. 227 p.

Karraker, N.E.; Welsh, H.H., Jr. 2006. Long-term impacts of even-aged timber management on abundance and body condition of terrestrial amphibians in northwestern California. Biological Conservation. 131(1): 132–140. https://doi.org/10.1016/j.biocon.2006.02.013.

Kluber, M.R.; Olson, D.H.; Puettmann, K.J. 2008. Amphibian distributions in riparian and upslope areas and their habitat associations on managed forest landscapes in the Oregon Coast Range. Forest Ecology and Management. 256(4): 529–535. https://doi.org/10.1016/j.foreco.2008.04.043.

Kluber, M.R.; Olson, D.H.; Puettmann, K.J. 2009. Downed wood microclimates and their potential impact on plethodontid salamander habitat in the Oregon Coast Range. Northwest Science. 83(1): 25–34. https://doi.org/10.3955/046.083.0103.

Kroll, A.J.; Garcia, T.S.; Jones, J.E.; Dugger, K.; Murden, B.; Johnson, J.; Peerman, S.; Brintz, B.; Rochelle, M. 2015. Evaluating multi-level models to test occupancy state responses of plethodontid salamanders. PloS ONE. 10(11): e0142903. https://doi.org/10.1371/journal.pone.0142903.

Lanctôt, C.; Grogan, L.F.; Tunstill, K.; Melvin, S.D. 2024. Metabolomic response of striped marsh frog (*Limnodynastes peronii*) tadpoles exposed to the fire retardant Phos-Chek LC95W. Comparative Biochemistry and Physiology, Part C. 276: 109786. https://doi.org/10.1016/j.cbpc.2023.109786.

Leclair, M.H.; Levasseur, M.; Leclair, R., Jr. 2008. Activity and reproductive cycles in northern populations of the red-backed salamander, *Plethodon cinereus*. Journal of Herpetology. 42(1): 31–38. https://doi.org/10.1670/06-234R2.1.

Maguire, C.C.; Manning, T.; West, S.D.; Gitzen, R.A. 2005. Green-tree retention in managed forests: post-harvest responses of salamanders. In: Peterson, C.E.; Maguire, D.A., eds. Balancing ecosystem values: innovative experiments for sustainable forestry. Gen. Tech. Rep. PNW-GTR-635. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 265–270.

Major, D.J. 2005. Effects of fire disturbance on terrestrial salamanders in mixed-coniferous forests of the Klamath/Siskiyou region of the Pacific Northwest. Logan, UT: Utah State University. 112 p. Ph.D. dissertation.

McComb, W.C.; McGarigal, K.; Anthony, R.G. 1993. Small mammal and amphibian abundance in streamside and upslope habitats of mature Douglas-fir stands, western Oregon. Northwest Science. 67(1): 7–15.

McEntire, K.D. 2016. Arboreal ecology of Plethodontidae: a review. Copeia. 104(1): 124–131. https://doi.org/10.1643/OT-14-214.

McIntyre, A.; Pope, K.L.; Cummings, A.K.; Wheelock, S.J.; Piovia-Scott, J. 2025. The effects of nearshore forest thinning on upland habitat use by pond-breeding amphibians in a montane coniferous forest. Forests. 16(7): 1059. https://doi.org/10.3390/f16071059.

McIntyre, A.P.; Schmitz, R.A.; Crisafulli, C.M. 2006. Associations of the Van Dyke's salamander (*Plethodon vandykei*) with geomorphic conditions in headwall seeps of the Cascade Range, Washington State. Journal of Herpetology. 40(3): 309–322. https://www.jstor.org/stable/4092999.

Naughton, G.P.; Henderson, C.B.; Foresman, K.R.; McGraw, R.L., III. 2000. Long-toed salamanders in harvested and intact Douglas-fir forests of western Montana. Ecological Applications. 10(6): 1681–1689. https://doi.org/10.1890/1051-0761(2000)010[1681:LTSIHA]2.0.CO;2.

Nicholson, K.E., ed. 2025. Scientific and standard English names of amphibians and reptiles of North America north of Mexico, with comments regarding confidence in our understanding. 9th ed. Society for the Study of Amphibians and Reptiles. 87 p. https://webapps.fhsu.edu/ksHerp/bibFiles/32018.pdf. (December 30, 2025).

Olson, D.H.; Ares, A. 2022. Riparian buffer effects on headwater-stream vertebrates and habitats five years after a second upland-forest thinning in western Oregon, USA. Forest Ecology and Management. 509: 120067. https://doi.org/10.1016/j.foreco.2022.120067.

Olson, D.H.; Burton, J.I. 2014. Near-term effects of repeated-thinning with riparian buffers on headwater stream vertebrates and habitats in Oregon, USA. Forests. 5(11): 2703–2729. https://doi.org/10.3390/f5112703.

Olson, D.H.; Clayton, D.; Reilly, E.C.; Nauman, R.S.; Devlin, B.; Welsh, H.H., Jr. 2007. Conservation strategy for the Siskiyou Mountains salamander (*Plethodon stormi*), northern portion of the range. Version 1.0. U.S. Department of Agriculture, Forest Service, Region 6, and U.S. Department of the Interior, Bureau of Land Management, Interagency Special Status and Sensitive Species Program. 47 p. https://andrewsforest.oregonstate.edu/publications/3804.

Olson, D.H.; Cousins, C.D. [in press]. Fire and fuel management considerations for aquatic-riparian amphibians. In: Wright, V.; Keville, M., tech. eds. Wildland fire and fuels science synthesis: supporting landscapeand community resilience in the Pacific Northwest. Gen. Tech. Rep. PNW-GTR-1044. Manuscript in preparation. On file with: D. Olson, Pacific Northwest Research Station, 3200 SW Jefferson Way, Corvallis, OR 97331.

Olson, D.H.; Kluber, M.R. 2014. Plethodontid salamander distributions in managed forest headwaters in western Oregon, USA. Herpetological Conservation and Biology. 9(1): 76–96.

Olson, D.H.; Leirness, J.B.; Cunningham, P.G.; Steel, E.A. 2014. Riparian buffers and forest thinning: effects on headwater vertebrates 10 years after thinning. Forest Ecology and Management. 321: 81–93. https://doi.org/10.1016/j.foreco.2013.06.013.

Olson, D.H.; Nauman, R.S.; Ellenburg, L.L.; Hansen, B.P.; Chan, S.S. 2006. *Ensatina eschscholtzii* nests at a managed forest site in Oregon. Northwestern Naturalist. 87(3): 203–208. https://doi.org/10.1898/1051-1733(2006)87[203:eenaam]2.0.co;2.

Olson, D.H.; Rugger, C. 2007. Preliminary study of the effects of headwater riparian reserves with upslope thinning on stream habitats and amphibians in western Oregon. Forest Science. 53(2): 331–342. https://doi.org/10.1093/forestscience/53.2.331.

Ovaska, K. 1988. Spacing and movements of the salamander *Plethodon vehiculum*. Herpetologica. 44(4): 377–386. https://www.jstor.org/stable/3892401.

Ozeri, L.; Blaustein, L.; Polevikov, A.; Kneitel, J.; Rahav, E.; Horwitz, R. 2021. Effects of a fire retardant on the Near Eastern fire salamander *Salamandra infraimmaculata* and aquatic community structure: an experimental approach. Hydrobiologia. 848: 4713–4729. https://doi.org/10.1007/s10750-021-04670-2.

Peacock, R.L.; Nussbaum, R.A. 1973. Reproductive biology and population structure of the western red-backed salamander, *Plethodon vehiculum* (Cooper). Journal of Herpetology. 7(3): 215–224. https://doi.org/10.2307/1563006.

Petranka, J.W. 1998. Salamanders of the United States and Canada. Washington, DC: Smithsonian Institution Press. 587 p.

Pilliod, D.S.; Bury, R.B.; Hyde, E.J.; Pearl, C.A.; Corn, P.S. 2003. Fire and amphibians in North America. Forest Ecology and Management. 178(1–2): 163–181. https://doi.org/10.1016/S0378-1127(03)00060-4.

Pilliod, D.S.; Wind, E., eds. 2008. Habitat management guidelines for amphibians and reptiles of the northwestern United States and western Canada. Technical Publication HMG-4. Birmingham, AL: Partners in Amphibian and Reptile Conservation. 139 p. https://www.fs.usda.gov/r6/issssp/downloads/xvertebrates/cpt-ha-hr-nwparc-habitat-management-guidelines-200812.pdf. (December 30, 2025).

Raphael, M.G. 1988. Long-term trends in abundance of amphibians, reptiles, and mammals in Douglas-fir forests in northwestern California. In: Szaro, R.C.; Severson, K.E.; Patton, D.R., eds. Management of amphibians, reptiles, and small mammals in North America. Proceedings of the Symposium, July 19–21, 1988, Flagstaff, Arizona. Gen. Tech. Rep. RM-166. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 23–31. https://www.fs.usda.gov/rm/pubs_rm/rm_gtr166.pdf. (December 30, 2025).

Raphael, M.G.; Bisson, P.A.; Jones, L.L.C.; Foster, A.D. 2002. Effects of streamside forest management on the composition and abundance of stream and riparian fauna of the Olympic Peninsula. In: Johnson, A.C.; Haynes, R.W.; Monserud, R.A., eds. Congruent management of multiple resources: proceedings from the wood compatibility initiative workshop. Gen. Tech. Rep. PNW-GTR-563. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 27–40. https://doi.org/10.2737/PNW-GTR-563.

Reilly, S.B.; Wake, D.B. 2019. Taxonomic revision of black salamanders of the *Aneides flavipunctatus* complex (Caudata: Plethodontidae). PeerJ. 7: e7370. https://doi.org/10.7717/peerj.7370.

Rochester, C.J.; Brehme, C.S.; Clark, D.R.; Stokes, D.C.; Hathaway, S.A.; Fisher, R.N. 2010. Reptile and amphibian responses to large-scale wildfires in southern California. Journal of Herpetology. 44(3): 333–351. https://doi.org/10.1670/08-143.1.

Rundio, D.E.; Olson, D.H. 2007. Influence of headwater site conditions and riparian buffers on terrestrial salamander response to forest thinning. Forest Science. 53(2): 320–330. https://doi.org/10.1093/forestscience/53.2.320.

Russell, K.R.; Van Lear, D.H.; Guynn, D.C., Jr. 1999. Prescribed fire effects on herpetofauna: review and management implications. Wildlife Society Bulletin. 27(2): 374–384. https://www.jstor.org/stable/3783904.

Semlitsch, R.D.; Bodie, J.R. 2003. Biological criteria for buffer zones around wetlands and riparian habitats for amphibians and reptiles. Conservation Biology. 17(5): 1219–1228. https://doi.org/10.1046/j.1523-1739.2003.02177.x.

Stephens, P.N. 2023. Large downed wood as post-fire refugia for terrestrial salamanders in Pacific Northwest forests. Corvallis, OR: Oregon State University. 41 p. M.S. thesis.

Sterrett, S.C.; Brand, A.B.; Fields, W.R.; Katz, R.A.; Grant, E.H.C. 2015. *Plethodon cinereus* (eastern red-backed salamander) movement. Herpetological Review. 46(1): 71.

Taub, F.B. 1961. The distribution of the red-backed salamander, *Plethodon c. cinereus*, within the soil. Ecology. 42(4): 681–698. https://doi.org/10.2307/1933498.

Thurman, L.L.; Stein, B.A.; Beever, E.A.; Foden, W.; Geange, S.R.; Green, N.; Gross, J.E.; Lawrence, D.J.; LeDee, O.; Olden, J.D.; Thompson, L.M.; Young, B.E. 2020. Persist in place or shift in space? Evaluating the adaptive capacity of species to climate change. Frontiers in Ecology and the Environment. 18(9): 520–528. https://doi.org/10.1002/fee.2253.

U.S. Department of Agriculture, Forest Service [USDA FS]. 2011. Nationwide aerial application of fire retardant on National Forest System land. Final environmental impact statement. Washington, D.C.: U.S. Department of Agriculture, Forest Service, Fire and Aviation Management. 544 p.

U.S. Department of the Interior, Bureau of Land Management; U.S. Department of Agriculture, Forest Service [USDI BLM and USDA FS]. 2022. Interagency Special Status/Sensitive Species Program. https://www.fs.usda.gov/r6/issssp/search/taxonomy.php. (February 2, 2025).

Vreeland, J.K.; Tietje, W.D. 2000. Numerical response of small vertebrates to prescribed fire in California oak woodland. In: Ford, W.M.; Russell, K.R.; Moorman, C.E., eds. The role of fire in nongame wildlife management and community restoration: traditional uses and new directions. Gen. Tech. Rep. NE-288. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station: 100–110.

Welsh, H.H., Jr.; Lind, A.J. 1991. The structure of the herpetofaunal assemblage in the Douglas-fir/hardwood forests of northwestern California and southwestern Oregon. In: Ruggiero, L.F.; Aubry, K.B.; Carey, A.B.; Huff, M.H., tech. coords. Wildlife and vegetation of unmanaged Douglas-fir forests. Gen. Tech. Rep. PNW-GTR-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 395–414. https://doi.org/10.2737/PNW-GTR-285.

Wilk, R.J.; Ricklefs, J.D.; Raphael, M.G. 2014. Abundance of western red-backed salamanders (*Plethodon vehiculum*) in the Washington Coast Range after headwater stream-buffer manipulation. Northwestern Naturalist. 95(2): 92–102. https://doi.org/10.1898/NWN13-28.1.