Wildfire, Fuel Reduction, and Herpetofaunas across Diverse Landscape Mosaics in Northwestern Forests

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Abstract: *The herpetofauna (amphibians and reptiles) of northwestern forests (U.S.A.) is diverse, and many species are locally abundant. Most forest amphibians west of the Cascade Mountain crest are associated with cool, cascading streams or coarse woody material on the forest floor, which are characteristics of mature forests. Extensive loss and fragmentation of habitat resulted from logging across approximately 50% of old-growth forests in northern California and approximately 80% of stands in Oregon and Washington. There is a complex landscape mosaic and overlap of northern and southern biotic elements in the Klamath-Siskiyou Region along the Oregon and California border, creating a biodiversity hotspot. The region experiences many low-severity fires annually, punctuated by periodic major fires, including the Biscuit fire, the largest in North America in 2002. In the fire's northern portion, severe fire occurred on >50% of stands of young, managed trees but on only about 25–33% of old-growth stands. This suggests that the legacy of timber harvest may produce fire-prone stands. Calls for prescribed fire and thinning to reduce fuel loads will remove large amounts of coarse woody material from forests, which reduces cover for amphibians and alters nutrient inputs to streams. Our preliminary evidence suggests no negative effects of wildfire on terrestrial amphibians, but stream amphibians decrease following wildfire. Most reptiles are adapted to open terrain, so fire usually improves their habitat. Today, the challenge is to maintain biodiversity in western forests in the face of intense political pressures designed to "prevent" catastrophic fires. We need a dedicated research effort to understanding how fire affects biota and to proactively investigate outcomes of fuel-reduction management on wildlife in western forests.*

Incendios, Reducción de Combustibles y Herpetofaunas en Mosaicos Paisajísticos Diversos en Bosques Noroccidentales

Resumen: *La herpetofauna (anfibios y reptiles) de bosques noroccidentales (E. U. A.) es diversa y muchas especies son localmente abundantes. La mayoría de anfibios de bosques al oeste de la cresta de Cascade Mountain están asociados con arroyos escalonados frescos o con material leñoso grueso sobre el suelo, que son característicos de bosques maduros. La tala produjo pérdida extensiva y fragmentación del hábitat en ~50% de los bosques maduros en el norte de California y en ~80% de los bosques en Oregon y Washington. En la Región Klamath-Siskiyou a lo largo de la frontera de Oregon y California hay un complejo mosaico paisajístico y traslape de elementos bióticos del norte y del sur, lo que produce un área crítica para la biodiversidad. En la región se presentan anualmente muchos incendios de baja severidad, punteados por incendios mayores periódicos, incluyendo el Biscuit fire, el más grande de Norteamérica en 2002. En la porción norte del incendio, hubo fuego severo en >50% de árboles jóvenes bajo manejo pero solo 25–33% de áreas de bosque maduro. Esto sugiere que el legado de la actividad maderera puede producir zonas propensas al fuego. La utilización de fuego prescrito y la eliminación de combustibles removerá grandes cantidades de material leñoso grueso de los bosques, lo que reduce la cobertura para anfibios y altera la entrada de nutrientes a los arroyos. Nuestra evidencia preliminar sugiere que los incendios no tienen efectos negativos en los anfibios terrestres, pero los anfibios de arroyo decrecen después del incendio. La mayoría de los reptiles están adaptados a terrenos abiertos, así que el fuego generalmente mejora su hábitat. Hoy, el reto es mantener la biodiversidad de los bosques occidentales frente a intensas presiones políticas diseñadas para "prevenir" incendios catastróficos.*

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Requerimos de esfuerzos de investigación especializada para entender los efectos del fuego sobre la biota e investigar proactivamente las consecuencias de la gestión de reducción de fuego sobre la vida silvestre en bosques occidentales.

Introduction

Even with satellite imagery, geographic information systems (GIS), detailed planning, and intensive management plans, perplexing riddles remain about forests in western North America. For example, timber harvest and effective fire suppression dominated the landscape over most of the last century. Then, from the early 1990s to the present, logging decreased drastically yet the woods burned extensively and severely. Why?

To answer this question, we need to examine our knowledge about wildfire and biodiversity in forested ecosystems. Wildfire is a natural, recurring disturbance in western forests, but aggressive fire-fighting efforts have suppressed most wildfires in the last 50 years (Pyne 1982; Agee 1993). Fire prevention and suppression were past priorities to protect timber resources, but an unintended result was accumulation of fuel loads (Agee 1988; Backer et al. 2004 [this issue]).

The outbreak of recent large fires, combined with well-publicized deaths of fire fighters and extensive loss of property, have elevated concern about effective management of wildfire, especially on public lands in the wildland-urban interface. Recent national initiatives to prevent conflagrations include the National Fire Plan (U.S. Department of Agriculture Forest Service 2000) and the Healthy Forest Initiative (U.S. Department of Agriculture Forest Service 2003). These efforts focus on reducing fuel loads and restoration of fire-adapted forests in the West. Because of these heightened activities, we are entering an unprecedented period of intense human intervention, regulations, practices, and policy of forest management related to fire.

Many amphibian species have declined across their ranges in the West (Bury et al. 1980; Blaustein & Wake 1990; Corn 2000); thus, information on their responses to fire and fuel-reduction practices is critically needed. Also, amphibians are of high conservation concern because many species have restricted geographical ranges, are listed as threatened or endangered, or only occur in specialized habitats. My objective was to synthesize our current knowledge of wildfire and the legacy of past logging that affects reptiles and amphibians and to explore means to better protect resident wildlife in the process of restoring fire to habitats in western forests. I focus on the Klamath-Siskiyou region (K-S) of southern Oregon and northern California because of (1) its great diversity of landscapes and herpetofauna, (2) the varied histories of timber harvest and fire, and (3) the largely untested prescriptions for reducing fuel loads over extensive acreage.

Old-Growth Forests, Logging, and Fire Prevention

Timber harvest in the Pacific Northwest occurred over 50% of old-growth forests in northern California and 80–90% of stands in Oregon and Washington, mostly between 1950 and 1995 (Spies & Franklin 1988; Smith et al. 1998). This resulted in extensive forest fragmentation. Logging decreased in the 1990s because of the existence of fewer old-growth parcels and the establishment of many late-successional reserves on federal lands. The landscape is now dominated by young stands (Franklin et al. 2002).

In the last 5 years, severe and extensive wildfires raged throughout the West. This partly reflects ignition of fuels that accumulated for many decades as a result of effective fire suppression in the past, coupled with drought conditions that have exacerbated the severity of fires. Today, forest-management policies are directed at reduction of the extent, frequency, and severity of fires, particularly where they threaten human lives and property. Stand thinning, prescribed burning, natural fires (e.g., allowing fire to burn within wilderness areas), and other fuels-management practices are increasingly used to reduce ground-layer fuel loads in western forests (Agee 1993; Bury et al. 2002). Forest thinning usually includes harvest of small-diameter trees and shrubs, which reduces the fuel base and the ability of fire to "ladder" up into the forest canopy as a crown fire, which is difficult to contain.

Often, the cut material and natural downed wood are piled and dried, then burned later in the rainy season. Thinning is often proposed to replace "unhealthy" (fire-prone) forests with stands that have widely spaced and large trees with little flammable material in the understory or on the ground. Thinning is expensive because it requires mechanical or hand extraction of fuels material. Harvest of some large trees of high economic value may be included in contracts as incentives to offset the high costs of thinning operations.

The other widely used technique to lessen future fire severity is prescribed burning, which usually involves a ground fire that burns up stores of shrubs, small trees, downed woody material, and leaf litter. These fires are set after the onset of fall rains or in spring before the end of the rainy season. They do not mimic wildfires that generally occur in the dry, hot summers. Thinning and

more precipitation on coastal, western slopes than on the leeward sides of the Coast Range or interior valleys. The topography is highly variable with steep terrain (0 to 1500 m elevation), and north-facing slopes are mesic compared with drier and hotter south sides of mountains. Forest conditions range from dense redwood (*Sequoia*) stands along the humid Pacific Coast through Douglas-fir (*Pseudotsuga menziesii* [Mirb.]) and mixed stands, to more open stands of pine, to oak woodlands and chaparral scrub or grasslands inland or on east-facing slopes with more xeric conditions. All this occurs in 25–50 km from the coast. There is a spectrum of environmental conditions and the herpetofauna respond to the amount and quality of available habitat. Local populations peak in the most suitable conditions for each species (Fig. 1).

The K-S region has 38 species, about equally composed of amphibians and reptiles, which is the highest species richness of the herpetofauna in the Pacific Northwest (Bury & Pearl 1999; Olson et al. 2001). There are four species of terrestrial salamanders endemic to the K-S region, but most of its species richness is due to the overlap of two major biogeographic elements, the northern and southern herpetofaunas (Peabody & Savage 1958). Many K-S amphibians depend on or are associated with characteristics of old-growth forests: upland habitats with much downed wood and streams with cool (<18° C), cascading waters. Fire-return intervals are about every 100 years in wetter areas of temperate forests, but may be 1–2 decades in xeric conditions on south-facing slopes or in the interior (Agee 1993). Further, some shrub, oak, and pine communities experience fire more frequently, depending on drought conditions.

Reptiles

With a few exceptions, reptiles flourish in interior locations or slopes with a hot, xeric climate (Fig. 1). Most reptiles prefer grassland, chaparral, oak woodlands, or open forest (Bury & Pearl 1999; Altman et al. 2001). Prescribed fire had no negative effects on reptiles in oak woodlands of central California (Vreeland & Tietje 2002). To my knowledge, no studies have addressed the question of how reptiles in Pacific Northwest forests respond to fire. However, the opening of closed forest canopies or dense shrub by fire or timber harvest benefits most species of reptiles (Means & Campbell 1980; Russell et al. 1999; Ford et al. 2002). Such alterations of habitat may be particularly important to species such as striped racers and whiptail lizards that require open, xeric terrain.

Terrestrial Amphibians

There are few published studies on the effects of fire on terrestrial amphibians in the Pacific Northwest. However, pitfall trapping in Northwest forests (Bury et al. 1991*a*; Corn & Bury 1991; Ruggerio et al. 1991) indicates no significant differences in the species richness or abundance of common species of terrestrial salamanders and migratory amphibians (e.g., Rough-skin newt [*Taricha granulosa*]) across stands that range from young (40–75 years old) to old growth (150–450 years old); this is chronosequential natural regeneration, primarily from wildfire. Hand searches show more individuals of terrestrial salamanders in older forests than in young, natural stands (Welsh 1990). There are more species and numbers of individuals of terrestrial salamanders in natural forests (>40 years old) than in logged stands (Welsh 1990; Bury 1994; Welsh & Lind 1995; Smith et al. 1998; Welsh & Droege 2001). Similar results occur in logged stands in deciduous forests in the eastern United States (Petranka et al. 1993; deMaynadier & Hunter 1995).

Preliminary results at two study areas in the K-S region (Bury et al. 2002) indicate no reduced numbers of terrestrial amphibians in areas subjected to wildfire compared with adjacent unburned sites. However, detections of terrestrial salamanders may differ in these burned and unburned plots because of sampling bias. Fire engulfed much of the leaf litter and small pieces of coarse woody material on the forest floor. Large amounts of leaf litter and downed woody material occur in unburned stands, which make it much more difficult to detect salamanders during timed searches (e.g., 6 hours of searching in each plot). This relationship is under separate study (D. J. Major, personal communication). Also, numbers of individuals may not be reduced in burned areas because most wildfires in the West occur during hot, dry summers, when terrestrial salamanders are deep underground for the season. Prescribed burns are set from fall to spring during the wet season, which is the period of surface activity for terrestrial salamanders and may result in mortality. However, we lack empirical evidence of this mortality.

Stream Amphibians

Three families of stream amphibians are endemic to the Pacific Northwest, and all require rocky, cool-water streams (Nussbaum et al. 1983; Adams & Bury 2002; Welsh & Lind 2002): torrent salamanders (*Rhyacotriton*, 4 species), Pacific giant salamanders (*Dicamptodon*, 4 species), and tailed frogs (*Ascaphus*, 2 species). In small streams, aquatic amphibians are particularly important in ecosystem function because they are more numerous and have greater biomass than salmonid fishes (Bury et al. 1991*b*). The tailed frog and torrent salamander are negatively affected by the elevated stream temperatures and increased sediment loads that result from clearcut logging (Bury 1988; Corn & Bury 1989; Dupuis & Steventon 1999; Biek et al. 2002; Welsh & Lind 2002). The Northwest Forest Plan promotes protection of riparian buffers,

These teams need to be established in every major region so that differences in climate, topography, and other features across the West are considered.

We need better assessments of how thinning and prescribed fire affect the biota, processes, and functions of western ecosystems. Thus, we face several complex challenges: (1) reducing the risk of catastrophic fires, especially in the urban-wildland interface; (2) determining the type, quantity, and quality of leaf litter and downed wood used by resident wildlife; and (3) predicting the short- and long-term effects of fuels-management practices on the diversity and abundance of wildlife and their required habitat features.

Theory and some field research suggest that fire has mixed effects on wildlife, including the herpetofauna. These effects are dependent on fire severity, age of stands, and prior management practices in watersheds. Aquatic ecosystems are of special concern because many threatened stocks of salmonid fishes and stream amphibians require cool, flowing streams. Fortunately, progress has been made in understanding the responses of aquatic ecosystems to wildfire (Riemen et al. 2003) and in accumulating knowledge of western stream amphibians (Corn et al. 2003; Pilliod et al. 2003). In watersheds adversely affected by resource extraction (e.g., grazing, logging, mining) or recreation, wildfire can be expected to have severe effects on aquatic biota because of the additive effects that fire is expected to have on degraded ecosystems (Minshall et al. 1989; Gresswell 1999; Minshall 2003). Further, the recovery of stream ecosystems from the effects of fire is likely to be slow, sporadic, and incomplete where structure, function, and natural processes have been impaired or negatively altered by anthropogenic activities.

Continued lack of information on the effects of fire on fish and wildlife will impede development of ecologically sound management policies (Pilliod et al. 2003; Rieman et al. 2003) that strive to conserve biological diversity and ecological integrity. Current and proposed management actions to reduce fuel loads as suggested by the National Fire Plan and similar efforts do not appear to fully consider the quantity and quality of the resultant post-treatment habitat for resident wildlife. Thus, conservation biologists must better explore the responses of species and ecosystems to fire. These studies need to consider amounts of forest leaf litter and downed wood after fire, and whether animals become concentrated in the remaining cover.

Intervals and severity of fire have increased as a result of decades of fuels buildup on the landscape, drought, and, perhaps, the predominance of young managed stands that are more prone to fire than old-growth stands. New studies need to examine the relationships between the legacy of logging and fire intervals, and fire effects on herpetofaunas, in the Pacific Northwest. It is not time to shy away from these serious challenges because fuel treatments are underway or planned for millions of acres of forest and rangeland in the West.

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