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POST-BREEDING HABITAT USE BY ADULT BOREAL TOADS (*BUFO BOREAS*) AFTER WILDFIRE IN GLACIER NATIONAL PARK, USA

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***Abstract.*—Effects of wildfire on amphibians are complex, and some species may benefit from the severe disturbance of stand-replacing fire. Boreal Toads (*Bufo boreas boreas*) in Glacier National Park, Montana, USA increased in occurrence after fires in 2001 and 2003. We used radio telemetry to track adult *B. boreas* in a mosaic of terrestrial habitats with different burn severities to better understand factors related to the post-fire pulse in breeding activity. Toads used severely burned habitats more than expected and partially burned habitats less than expected. No toads were relocated in unburned habitat, but little of the study area was unburned and the expected number of observations in unburned habitat was < 3. High vagility of *B.* boreas and preference for open habitats may predispose this species to exploit recently disturbed landscapes. The long-term consequences of fire suppression likely have had different effects in different parts of the range of *B. boreas*. More information is needed, particularly in the northern Rocky Mountains, where toads are more likely to occupy habitats that have diverged from historic fire return intervals.**

Key Words.—amphibians; Boreal Toad; *Bufo boreas*; burn severity; fire; habitat use; Montana; radio telemetry

INTRODUCTION

Physical disturbance is essential to the creation and maintenance of landscape diversity and ecosystem processes, including population and community dynamics (Connell 1978; Picket and White 1985). Disturbance occurs over a range of intensities, from minor events with local effects to severe events with consequences across large landscapes. At the extreme end of the scale, catastrophic disturbance typically results in a major shift in community structure and can cause extirpation of some species (Petraitis et al. 1989; Pickett et al. 1989; Dale et al. 2005). Stand-replacement fire in western forests is a prime example of a catastrophic disturbance which is often viewed, particularly by the general public, politicians, and some land managers, as a destructive force with few benefits (Barker 2005). Reality is contrary to perception; fire in western forests promotes biological diversity by creating a mosaic of habitats with predictable changes in composition of groups such as insects (McCullough et al. 1998) and birds (Hutto 1995). For example, many species of birds are regularly more abundant in burned stands than in unburned stands (Kotliar et al. 2002; Smucker et al. 2005). However, aside from the salamander of mythology, amphibians are not usually considered to be high on the list of animals adapted or resilient to fire. Climate change is expected to contribute to more severe and frequent wildland fire in western forests (Fagre et al. 2003; Westerling et al. 2006), so there is a need to better understand effects of fire on amphibians (Pilliod et al. 2003; Bury 2004).

Most research on amphibians and fire has examined low-severity fires, such as managed prescribed burns (Russell et al. 1999; Lemckert et al. 2004; Langford et al. 2007). The effects of more severe stand-replacement fires on amphibians in western forests have been little studied (Pilliod et al. 2003; Bury 2004), possibly because severe fires have been infrequent and are not easily subject to experimentation (Hossack and Corn 2007). Bull (2006) found adult Boreal Toads (*Bufo boreas boreas*) in northwestern Oregon used habitats that had burned within the last 10 yr, but in proportion to the occurrence of these habitats on the landscape. Otherwise, we know little about use of burned terrestrial habitat by adult toads.

Although *B. boreas* is in serious decline in parts of the species' range in western North America (Muths and Nanjappa 2005), this species is thriving in some highly disturbed landscapes, such as the blast zone created by the 1980 eruption of Mount St. Helens (Crisafulli et al. 2005). Similarly, breeding by *B.* boreas increased from 0 to 7 sites and from fewer than 5 to > 20 sites after wildfires in 2001 and 2003, respectively, in Glacier National Park (NP), Montana (Hossack and Corn 2007). There was little evidence supporting the hypotheses that changes to the breeding sites in burned areas (e.g., temperature or nutrients; Hossack and Corn 2008) are influencing this increase in use. Thus, changes to the terrestrial environment may be playing a role in driving this change in breeding site distribution. Parallel to the studies of amphibian breeding sites following the wildfires of 2001 and 2003 in Glacier NP (Hossack and Corn 2007), we studied adult *B. boreas* (Fig. 1) in the mosaic of burned and unburned terrestrial habitats on the west side of Glacier NP. We compared use of habitat mosaics from severely burned to unburned to better understand factors related to the post-fire pulse in breeding activity.

FIGURE 1. Boreal Toad (*Bufo boreas boreas*) in Glacier National Park, Montana, USA. Photographed by Blake R. Hossack, USGS.

METHODS

***Study Area*.—**The Robert Fire, a stand-replacement wildfire, burned about 16,500 ha on the west side of Glacier NP, Montana, USA in July and August, 2003 (Fig. 2, 3; Hossack et al. 2006a). Most of the study area was covered with dense stands of Lodgepole Pine (*Pinus contorta*) and Western Larch (*Larix occidentalis*) with a historical fire frequency of 140-340 yr (Barrett et al. 1991). The southeastern portion of the study area was dominated by Western Redcedar (*Thuja plicata*)-Western Hemlock (*Tsuga heterophylla*) forests with mean historical fire return intervals of up to 450 yr (Barrett et al. 1991). The initiation date of stands in the study area ranged from 1628 to 1926 (Barrett et al. 1991).

We characterized habitat and use by *B. boreas* at three study sites within the study area. Each study site consisted of a central wetland or pair of wetlands used for breeding by ≥ six toads and the surrounding terrestrial habitats within 1 km of the wetland center (Fig. 3). We used a GIS with a burn severity data layer provided by Carl Key (USGS, Glacier National Park, West Glacier, MT) to quantify the area within each study site according to three fire severity categories: unburned (no evidence of fire); partially burned (some unburned understory or canopy foliage present); and severely burned (no unburned foliage present). These are fewer than the burn severity classifications available in the data layer, but it was difficult in the field to distinguish reliably among intermediate burn categories. Therefore, for accuracy, and to maximize the contrast in our analysis, we combined low and moderate burn severities as partially burned.

Burn severity classifications are based on the fire's effect on vegetation and soils, determined by combining indices derived from satellite imagery and field plots (Key and Benson 2005). Although the Robert Fire is considered a stand-replacing fire, typical for the region, it burned with mixed severity (Fig. 3). Within the fire perimeter, 24% of the area burned at high severity, 57% of the area was partially burned, and 19% of the area was unburned. The study sites were located in an area of relatively higher fire severity. Of the 849.8 ha within the three study sites (92.7 ha were covered by the surface of Lake McDonald outside the fire perimeter), 24.1 ha (2.8%) were unburned, 448.4 ha (52.8%) were partially burned, and 377.3 ha (44.4%) were severely burned.

***Vegetation Sampling*.—**To measure differences in vegetation and structural characteristics among burn severity classes that may influence habitat use by toads, we sampled 36 systematically selected plots divided evenly among the three burn severity classes, in each of three study sites (Fig. 3). These plots were associated with a complementary study and do not necessarily represent the distribution of vegetation characteristics across the landscape, but they should accurately characterize the differences in general habitat characteristics among our fire severity categories. At each of the 108 vegetation plots, we used a moosehorn densitometer to evaluate the presence or absence of tree canopy, shrubs, forbs, grasses, groundcover, downed wood, and bare ground at 21 points within a 5-m radius circle. Data for each plot were summarized as the proportion of the 21 points that contained each vegetation or cover type. These measurements were taken toward the end of the 2004 field season and reflect the regrowth that occurred during the 12 months after the

FIGURE 2. The Robert Fire burns on Howe Ridge, across Lake McDonald in Glacier National Park, Montana, USA on 10 August 2003. Photographed by USGS.

fire. The vegetation data were summarized using Principal Components Analysis with varimax rotation on the correlation matrix to reduce the seven measures into orthogonal axes.

Habitat Use.—We captured 22 adult *B. boreas* (6-8 per study site) in May and June 2004, fitted each one with a Titley Electronics LT-2 radio transmitter (Ballina, NSW, Australia), and measured mass and snout-vent length (SVL). One toad was initially fitted with a transmitter in late July, 2004. We affixed transmitters using adjustable Velcro waist belts (David Schmetterling, pers. comm.). The smallest toad fitted with a transmitter was 34 g. Transmitters with belts averaged 2 g. We attempted to relocate each toad at least once every 3-5 days during the daytime using a Communications Specialists R-1000 receiver (Orange, CA, USA) with a Telonics RA-14 antenna (Mesa, AZ, USA). The effective range of these transmitters was 100-300 m in our study area. Relocations typically included visual contact unless an animal was in a burrow or thick vegetation. We recorded burn severity, microhabitat (under log, in burrow, open, in vegetation), and air temperature during each relocation event. We restricted relocations to daytime hours to minimize opportunities for hazardous encounters with bears.

We recaptured toads at least once every 15 days to evaluate the fit of their waist belts and to check the health of the animals. If toads developed sores from the waist belts, we treated them with Bactine and their belts were adjusted to prevent further abrasion. If no radio signal was detected during a relocation attempt, we repeatedly searched outward from the last known

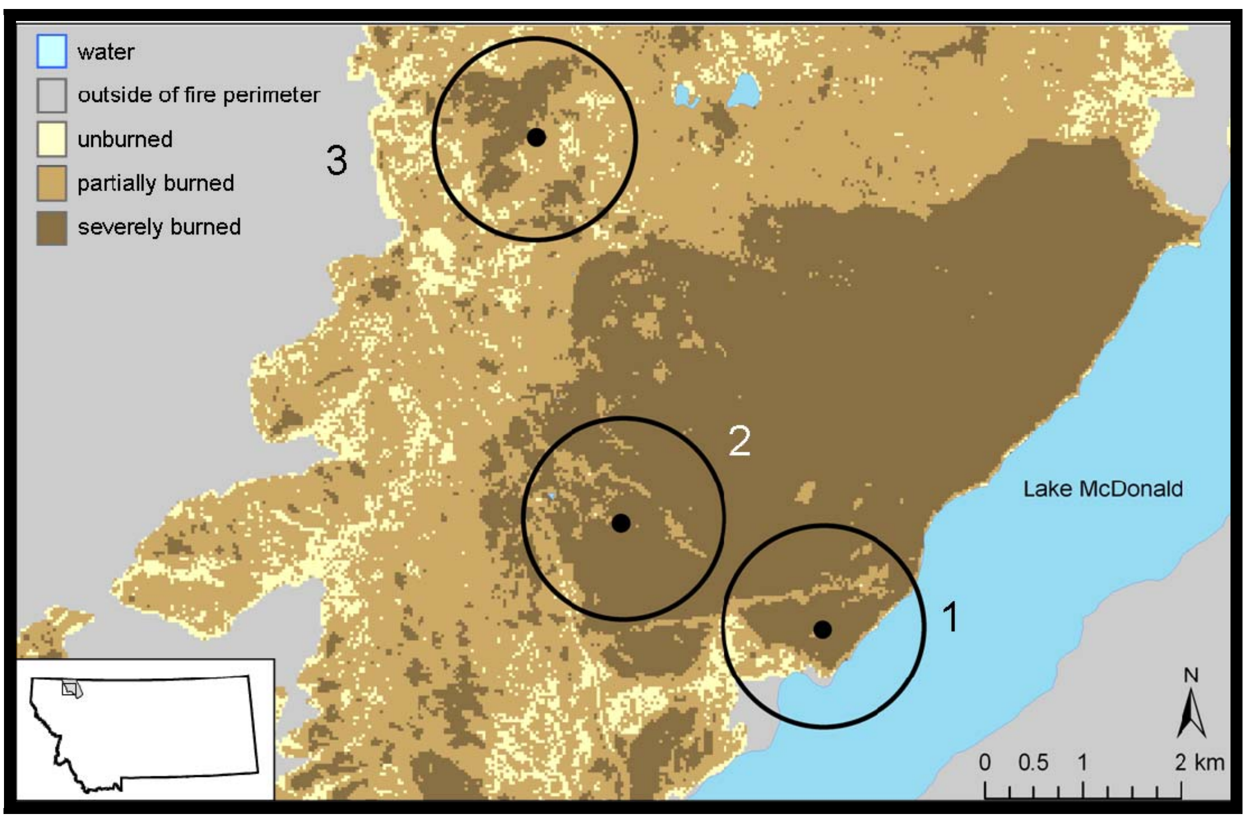

FIGURE 3. Study sites used in evaluating responses of *Bufo boreas* to wildfire in Glacier National Park, Montana, USA. Black circles represent 1-km radii centered on breeding pond(s) where toads were initially located. Site numbers 1, 2, and 3 (from south to north) are overlain on a Robert Fire burn severity map.

TABLE 1. Variable loadings and the eigenvalues (λ) of the first 2 factors summarizing vegetation characteristics that were measured in 108 plots. The data were summarized using Principal Components Analysis with varimax rotation of the correlation matrix.

Variable	Factor 1	Factor 2
Bare ground	-0.90	-0.21
Ground cover	0.88	0.27
Shrubs	0.80	0.26
Forbs	0.72	-0.43
Canopy	0.68	0.45
Grasses	0.31	0.74
Downed wood	-0.06	-0.72
λ	3.31	1.62

location of an animal in concentric circles, increasing the radius by about 200 m with each circle. Beginning in mid-August, we recaptured animals and removed the transmitters.

***Analysis*.—**Eight toads did not contribute any terrestrial observations; three died shortly after the transmitters were attached, and five either were never relocated after the initial capture or freed themselves from their transmitter before any terrestrial relocations were made. We excluded relocations of toads in water, which were rare after toads left the breeding ponds. Consequently, our analysis was based on 112 terrestrial observations from 14 toads (1-17 observations per toad, mean = 8.0) between the dates of 20 May and 17 August. Days between observations averaged 4.3 (range = 1-17). The data were analyzed as a Design I study, where all observations were considered independent and there was no analysis of use by individual animals (Neu et al. 1974).

We evaluated time and temperature trends in microhabitat use before testing whether toads used burn severities in proportion to their availability because we expected that use of microhabitats and burn severities were correlated. We grouped microhabitats into cover (log or burrow, n = 28), vegetation (grass or shrub, n = 50), and open (n = 33) categories for analysis and used 1-way ANOVA (α = 0.05) to test whether ordinal date and air temperature recorded during relocations differed among microhabitats. We analyzed expected and observed use of the different burn severities using program Resource Selection for Windows (Fred Leban, University of Idaho, Idaho, USA), which weighted availability and use of each burn severity by the number of telemetered animals in each of the three study sites. We compared observed and expected use using Bailey simultaneous 95% confidence intervals (Cherry 1996). Because no toads were relocated in unburned habitats, we first rescaled the partially and severely burned categories to sum to 1 and based our comparison of use versus availability only on those severities. We did not evaluate habitat use by gender because observations on the six females were comparatively rare (mean = 2.4 observations, range = 1-6) compared to those of the eight males (mean = 12.4 observations, range = 5-17).

We followed this initial comparison of use versus availability of different burn severities with a Logistic Regression analysis (α = 0.05) to determine whether use of partially and severely burned habitats was dependent upon time (ordinal date) or microhabitat use. Ordinal date was correlated (r = 0.57) with mean daily air temperature 6-km away at the West Glacier remote automated weather station (Desert Research Institute and the West Regional Climate Center. National Parks RAWS Page. Available fromhttp://www.wrcc.dri.edu/wraws/nidwmtF.html . [Accessed 15 January 2008].), and provided a better fit to the data than the weather station data (temperature, relative humidity, or precipitation). We included a microhabitat × ordinal date interaction term because we hypothesized that diurnal use of severely burned areas later in the season would be facilitated by decreased use of open microhabitats. We also included the three study sites as a blocking factor because the availability of burn severities was not equal in each and because toad behavior may have differed depending upon local microclimate.

RESULTS

Vegetation and structural characteristics differed among areas with different fire intensities (Fig. 4).

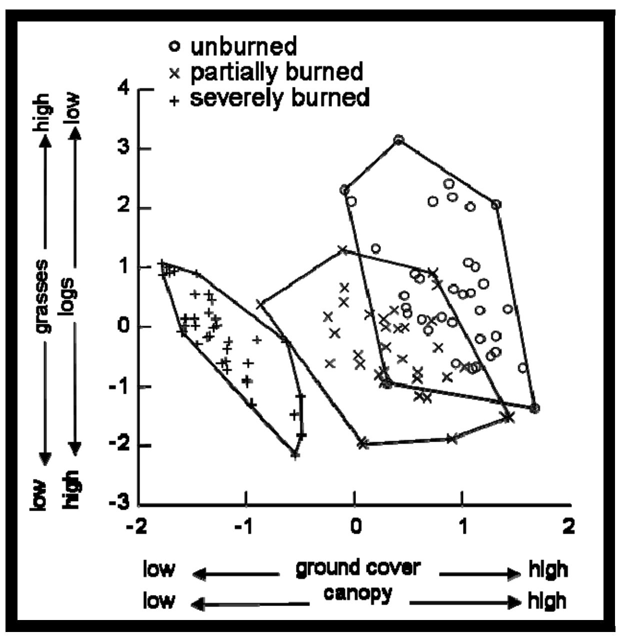

FIGURE 4. Values from the 108 vegetation plots plotted in principal components space. Points from each of the 3 fire severity classes are encompassed by a minimum convex polygon. See Table 1 for variable loadings on the factors.

Factor 1 explained 47% of the variation and is correlated with variation in vegetation and ground cover. Factor 2 explained 23% of the variation in the data set and is correlated with (or describes) variation in extent of grasses and quantity of downed logs (Table 1). Burned plots had less coverage by grasses and more downed wood; the increase in downed wood resulted from trees that fell after burning. High severity burn plots had the least variation in vegetative characteristics and did not overlap with the factor scores of partially-burned or unburned plots.

Despite the lack of nocturnal observations, surface activity by toads was high. Most observations (75%) were made away from retreat sites in vegetated or open microhabitats. Use of microhabitats was not significantly related to temperature measured at the time of observation (F = 2.05, df = 2,98, P = 0.134). Vegetated microhabitats were more likely to be used later in the summer than covered (mean difference = 12.2 days, P = 0.035 [Tukey's HSD]) or open (12.4 days, P = 0.02) microhabitats.

Toads used severely burned habitats more than expected and partially burned habitats less than expected. We recorded more than twice as many observations of toads in severely than in partially burned habitats, even though partially burned habitats were more common (Fig. 5). We never relocated toads in an unburned habitat. However, unburned habitats were rare in the study area, and we would have expected only 2.5% of observations in unburned habitats by chance. The exact 95% CI (Casella 1986) for 0 relocations (0-3.2%) includes the expected percentage of observations, so we cannot conclude that toads avoided unburned habitats. Selection for severely burned habitats decreased during the summer (ordinal date: b_1 = -0.054 [se = 0.021]; χ^2 = 5.93, df = 1, P = 0.015), but the shift in use was not related to the change in microhabitat use (χ^2 = 1.73, df = 2, P = 0.421), nor an interaction between microhabitat use and ordinal date (χ^2 = 1.67, df = 2, P = 0.435). Use of burn severities differed by study site, with greater use of severely burned areas in Site 2 than in Site 3 (χ^2 = 10.17, df = 1, P = 0.006). Overall, differences in use of burn severities by toads among study sites were consistent with differences in proportion of burn severities among these sites. Site 3 had the lowest proportion of severely burned forest of the three study sites, accompanied by the fewest number of relocations in that burn severity, and the Logistic Regression analysis did not account for availability of different burn severities. Site 3 also had the latest mean date of capture (27 June), which likely biased the relocation data toward more partially burned areas.

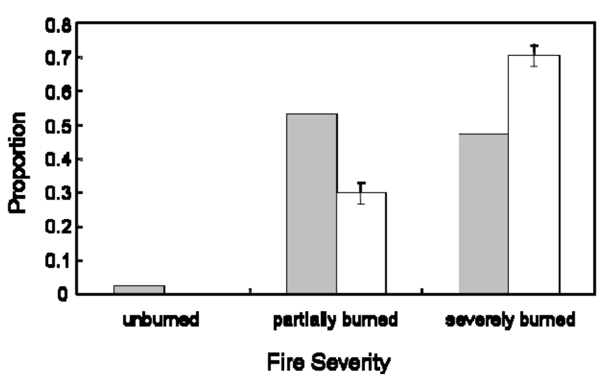

FIGURE 5. Expected (grey bars) and observed use (hollow bars; ± 95% CI) of different burn severities by radio telemetered *Bufo boreas* in Glacier National Park, Montana, USA. The confidence intervals were calculated after excluding the unburned category, for which there were zero observations.

DISCUSSION

It has long been known that *B. boreas* is a habitat generalist, observed to breed in diverse locations spanning roadside ditches to large reservoirs (Stebbins 1951). Recent observations indicate that these toads can exploit severely disturbed landscapes (Crisafulli et al. 2005; Hossack and Corn 2007), but the extent to which this species can be considered adapted to disturbance is unclear. However, at least two aspects of the biology of *B. boreas* appear to facilitate this species' use of recently disturbed habitats.

First, toads are among the most vagile anurans, and rapid immigration into burned areas is unlikely to pose a significant problem. Radio-tracking studies of *B. boreas* have recorded adult toads moving > 400 m in a single day (Bartelt et al. 2004), averaging > 200 m/day over several days (Bull 2006), and moving 2-6 km from the breeding pond during the summer (Bartelt et al. 2004; Muths 2003; Bull 2006). Adams et al. (2005) observed adult and juvenile *B.* boreas in Montana making movements of several hundred meters by floating or swimming downstream in small streams. At Mount St. Helens, six species of amphibians have colonized a wetland complex that is in the debris avalanche zone, where no amphibians are thought to have survived the 1980 eruption. *Bufo boreas* and Pacific Treefrogs (*Pseudacris regilla*) were the first species to appear, 3 yr after the eruption (Crisafulli et al. 2005).

Second, adult *B. boreas* prefer open habitats characteristic of disturbed sites to closed canopy coniferous forest. Bartelt et al. (2004) found that female toads were found in open forests (< 50 % canopy cover) more frequently than closed forests (> 50 % cover). Bull (2006) observed toads more frequently in sites with less cover and southern exposures. In our study, during the summer after the Robert Fire, we found adult toads most often in the severely burned areas, where there was no canopy cover. The critical factor in whether toads can exploit open habitats appears to be the presence of adequate retreat sites, where toads can escape predators and maintain water balance (Bartelt et al. 2004; Bull 2006). Results from physical models (Bartelt and

Peterson 2005) placed in our study areas suggest that toads could exploit severely burned areas without great risk of increased water loss as long as they use cover (unpubl. data). We suspect the shift in use by toads away from severely burned habitats later in the summer reflects a water conservation strategy, because partially burned areas had more ground and canopy cover and likely retained more soil moisture.

When we observed the increase in numbers of toad breeding sites after the recent fires in Glacier NP, our initial hypothesis was that the fires had made the breeding sites more attractive to toads. Previous work in Glacier NP showed that *B. boreas* was more likely to breed in wetlands that received greater sun exposure (Hossack et al. 2006b), a result consistent with other temperate *Bufo* (Banks and Beebee 1987; Skelly et al. 1999; Rannap et al. 2007), and we expected that the fire resulted in warmer wetland temperatures. However, there is little evidence to support this hypothesis (Hossack and Corn 2008). Instead, preference by adult toads for open terrestrial habitats may indirectly facilitate the increase in breeding activity after fire.

Vegetative growth is often associated with declines in presence of *Bufo* (Skelly et al. 1999; Rannap et al. 2007). Based on this and the use of burned and other disturbed landscapes by *B. boreas*, it is tempting to speculate that fire suppression during the past 100 yr could be related to the status of toads. However, the potential effects of fire suppression appear to run counter to trends in populations of *B. boreas*, which have suffered greater declines in the southern Rocky Mountains (Corn 2003; Muths et al. 2003; Muths and Nanjappa 2005) than in the northern reaches of its range (Corn et al. 2005; Wind and Dupuis 2002). Fire suppression has had relatively minor effects on the frequency of large fires in subalpine and montane forests (Schoennagel et al. 2004), which particularly are the primary habitat of *B. boreas* in the southern Rocky Mountains. Effects of fire suppression are greatest at lower elevations, particularly in drier Ponderosa Pine (*Pinus ponderosa*) forests that historically burned more frequently, resulting in denser, more uniform stands (Schoennagel et al. 2004; Veblen et al. 2000). Although the distribution of *B. boreas* in Colorado appears to have retreated from many lower elevation sites (Livo and Yeakley 1997), low-elevation, dry forest is marginal habitat for toads in Colorado. In western Montana, *B. boreas* occupies a broader range of habitats, from valley bottoms to alpine meadows including *P. ponderosa* forest, but the status of toad populations is in question (Maxell et al. 2003). The effects of fire suppression on northern populations need further investigation. The preference of toads for open habitats also suggests a need to know more about effects of direct habitat manipulation, including timber harvest and fuel reduction.

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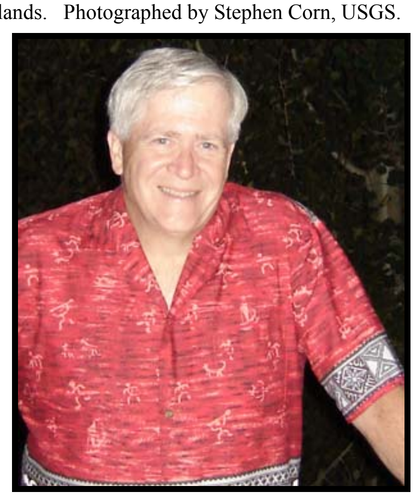

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