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RESPONSES OF WESTERN TOADS (*Bufo boreas*)
TO CHANGES IN TERRESTRIAL HABITAT
RESULTING FROM WILDFIRE

By

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Professional Paper

presented in partial fulfillment of the requirements
for the degree of

Master of Science
in Wildlife Biology

The University of Montana
Missoula, MT

Spring 2007

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ACKNOWLEDGEMENTS

I would like to thank Steve Corn and Blake Hossack with the USGS for setting me off on this direction and providing funding and support to make it possible; Lisa Eby for all her help, but especially her assistance with digging through the literature, writing the introduction, and designing the study; Jonathan Richardson for help in the field; Dan Pletscher for helping me get back on track and stay there; Jon Graham and Mabelle Wilson for their invaluable statistical support; Ute Langner for assistance deciphering the mysteries of GIS; Anne Greene for reviewing my writing; and, of course, Dalit Ucitel for her incessant encouragement in all matters important.

INTRODUCTION

Physical disturbances can play a major role in the creation and maintenance of landscape heterogeneity, ecosystem processes, and population and community dynamics. Pickett and White (1985:7) defined disturbance as “any relatively discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment.” Many natural processes (e.g., fires, floods, volcanic eruptions) and human impacts (e.g., timber harvest and mining) are considered disturbances under this definition. The effects of a disturbance depend not only on the type and magnitude of the disturbance, but also on the timing and frequency of its recurrence. Catastrophic disturbances can eliminate species, reduce biotic diversity, and alter community structure (Petraitis et al. 1989; Pickett et al. 1989). In contrast, less severe disturbances may result in increased biotic diversity by reducing abundances of competitively dominant species (Connell 1978; Petraitis et al. 1989), and/or increasing structural heterogeneity. Disturbances that occur at predictable intervals or as a result of seasonal phenomena can be integral to the functioning of ecosystems that have developed under such regimes. Unexpected events and anthropogenic activities including management practices (e.g., prescribed burns and controlled releases from reservoirs) may occur at times contrary to natural disturbance cycles.

Wildfires are one example of a disturbance that affects systems at the landscape scale and can be important for the maintenance of biotic composition and diversity within those systems. Wildfires create a mosaic of habitat types that benefit many species. Predictable changes in insect (McCullough et al. 1998) and bird (Hutto 1995) communities in boreal forests of the western U.S. have been documented following fires. Some species may not only benefit from fire, but may depend on conditions found in burned areas. For example, the adults of some species of jewel beetles (*Melanophila* spp.) are attracted to actively burning fires and their larvae develop almost exclusively in the wood of trees freshly killed by fire (Linsley 1943). Black-backed woodpeckers are also specialists on recently burned forests (Bock and Bock 1987; Murphy and Lehnhausen 1998); they enter newly burned areas and forage on wood-boring beetles, including *Melanophila* (J. Woolf, pers. comm.).

Suppression of fire has changed the regular disturbance regimes that historically affected forest and prairie ecosystems across the North America (Frost 1998; Smith 2000). In many cases, forests that were once mosaics of varying stand ages and patterns in crown cover have been simplified into similar-aged, late successional forests. The negative effects of fire suppression (e.g., increased fuel build-up) and the resulting large, high-intensity fires that have burned across the western U.S. have led to policies of more proactive fuel reduction that include commercial logging, thinning, and prescribed burning (USDA 2001). Although some researchers have examined the effects of timber harvest and prescribed burns versus wildfire with regard to small mammal communities (e.g., Ford et al. 1999; Simon et al. 2002), we do not know how these different disturbances affect most other taxonomic groups.

Amphibian responses to disturbances are species-specific, variable, and not well understood (Pilliod et al. 2003). Kirkland et al. (1996) found American toads (*Bufo americanus*) in higher abundances in burned than unburned areas; Greenberg (2001) found that canopy gaps created by wind disturbance had no effect on amphibian numbers in the southern Appalachians; and Skelly et al. (1999) found responses to canopy closure varied by species - the abundances of some species increased while others decreased. Human disturbances such as timber harvest are frequently cited as having negative effects on amphibian species and total amphibian diversity (deMaynadier and Hunter 1995, 1998; Dupuis 1997; Waldrick 1997). These effects, however, are not consistent across all studies or species. Some researchers have seen increased abundances of particular species, including toads, in harvested areas (deMaynadier and Hunter 1995).

Understanding how species respond to natural disturbances is necessary for conservation and management. This is especially important for taxonomic groups such as amphibians in which dramatic declines have been documented. Extirpation of amphibian populations has been observed worldwide and is a focus of growing concern (Stuart et al. 2004). Across its range, the western toad has experienced severe declines (Carey 1993; Corn 1994; Fisher and Shaffer 1996; Stuart and Painter 1994; Ross et al. 1995; Keinath and McGee 2005). Western toad numbers in the southern portions of its range have fallen so sharply that the species is protected in Wyoming, listed as endangered by the states of New Mexico and Colorado, and is a candidate for federal

listing under the Endangered Species Act (Loeffler 2001). In Colorado and Wyoming, Corn (2003) documented the near extirpation of western toad populations at high elevations in national parks and wilderness areas. In western Montana, historic accounts portray the western toad as being common, while recent studies (Maxell 2000) found this species far less abundant than would be expected. Within 40 random watersheds sampled in western Montana, western toad breeding was found at only 9 out of 347 potential sites. In addition, most of the breeding sites described by Maxell (2000) had very few (<5) individuals.

Multiple hypotheses have been suggested to explain the observed declines in amphibian populations. Although unlikely that a single hypothesis will explain the trends of decline throughout the range of the western toad, only 1 or 2 of the proposed hypotheses are supported. Many of the declining or extirpated populations of western toads have been at high elevations or in remote areas with minimal direct habitat loss and modification from development or other known causes (Corn 2003). Typically, habitat loss and modification are thought of in terms of discrete events (e.g., clearing of construction sites, draining wetlands, and clear-cutting forests) but do not include long-term and cumulative effects of other, less direct, anthropogenic activities (e.g., fire suppression). These less direct types of habitat alterations may have more subtle effects on natural processes over longer periods of time. Declines in some frog and toad species in the eastern United States have been attributed to canopy closure resulting from forest succession (Werner & Glennemeier 1999; Skelly et al. 2002). By considering habitat changes over the long-term (e.g., vegetation growth resulting from decades of fire suppression), habitat modification may account for some of the declines in western toad populations that have been observed.

Hossack et al. (in prep.) documented immediate dramatic increases in the numbers of western toad breeding sites in areas burned by wildfires in Glacier National Park. While these increases were consistent for multiple fires occurring across multiple years, no increases were documented in unburned areas of the park. These findings, along with studies of thriving populations of western toads in disturbed habitats such as the Mount Saint Helens blast zone (Crisafulli and Hawkins 1998) and observations of increased western toad abundances in burned forests in Oregon (E. Bull, pers. comm.)

and Idaho (B. Hossack, pers. comm.; D. Pilliod, pers. comm.) have led to the hypothesis that the western toad benefits from certain types of disturbances. If western toads are responding to disturbance, forest management practices (e.g., fire suppression) may play important roles in habitat suitability and demographics of some populations of this species.

In western Montana, western toads congregate at ponds in early spring to breed. After breeding, adult toads disperse into the surrounding terrestrial habitats. It is unclear whether the changes to aquatic or terrestrial habitat are more likely to be driving the increases in breeding that have been documented following disturbances. Hossack et al. (in prep) found no changes in aquatic habitat in burned areas that would provide obvious benefits for toad eggs or larvae.

Little is known about use of burned habitat by post-breeding adult western toads. In this study, I examined adult western toad use of the habitat mosaic created by a recent wildfire on the west side of Glacier National Park. My intent was to better understand what factors were related to the breeding pulse that followed the Moose Fire of 2001 (NB: Similar pulses were documented following the fires of 2003).

METHODS

Study Site Selection

My study took place on the west side of Glacier National Park during the summer of 2004. Potential study sites within the Robert Burn of 2003 were identified by comparing a detailed fire severity map of the area burned (Key and Benson, 2005) with past data on western toad breeding (USGS - unpublished data). Potential sites were chosen such that each contained the full range of burn severities that can result from wildfire (i.e., unburned through high severity [Table 1] as identified by the USGS). Three study sites were selected from all potential sites identified. Sites were selected opportunistically based on the presence of 6 or more adult toads. All three sites were east of the Camas Road (Glacier Route 8) between Lake McDonald and Howe Ridge. Each

site consisted of a central pond or pair of ponds used for breeding by western toads and the associated terrestrial habitats surrounding those ponds (Fig. 1).

Table 1. Definitions of burn severity classes used in evaluating responses of western toads to wildfire in Glacier National Park as categorized both during field measurements and in GIS.

<u>Burn Severity</u>	<u>Definition:</u>
(UB) Unburned	Field measures: No sign of fire GIS: Pixels classified as Unburned/Very low
(LM) Low to moderate	Field measures: Burned vegetation; canopy and/or under-story foliage remaining GIS: Pixels classified as Low, Enhanced Low, Moderate-low, and Moderate-high
(HS) High Severity	Field measures: No foliage remaining GIS: Pixels classified as High and Enhanced high

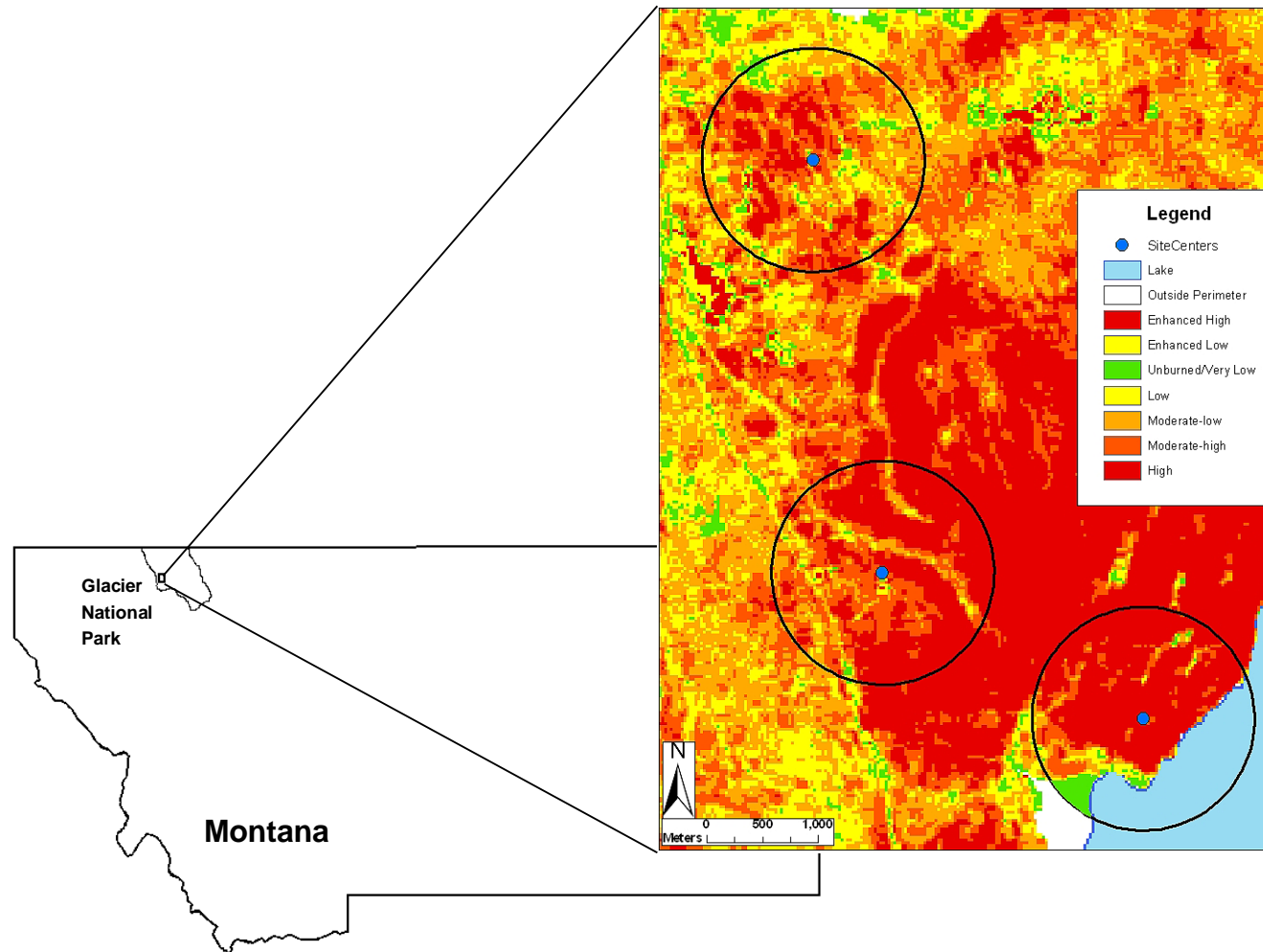


Fig 1. Study sites used in evaluating responses of western toads to wildfire in Glacier National Park. Black circles representing 1 km radii centered on breeding pond(s) where toads were initially located. Site numbers 1, 2, and 3 (from south to north) are overlain on Robert Fire burn severity map.

Habitat Use

Adult toads were caught at the ponds in May and June when they congregated to breed. We located toads at night by their eye-shine (Corben and Fellers 2001) or during the day by slowly walking through the ponds while scanning visually. Each animal was caught by hand, fitted with a radio transmitter, and weight (g) and snout-vent length (SVL) (mm) were recorded. Each animal was sampled for chytrid fungus at the times of initial and final capture by swabbing the animal's venter and preserving each swab in 95% ethanol (Livo 2004). These samples were sent to Pisces Molecular, Boulder, Colorado, where they were tested for the presence of chytrid DNA using polymerase chain reaction (PCR) methods (Boyle et al. 2004).

Post-breeding movement patterns and habitat use by western toads have been shown to differ by sex (Muths 2003; Bartelt et al. 2004); therefore individuals of both sexes were captured and marked. Each toad was radio-tagged with an LT-2 transmitter from Titley Electronics. We attached transmitters with velcro waistbelts following the methods of M. Young (USFS – Rocky Mountain Research Station) and D. Schmetterling (Montana Fish Wildlife and Parks) (M. Young, pers. comm.). Each transmitter weighed approximately 2.0g, had an average range between 100-300m, and a battery life of about 20 weeks. The minimum body weight of toads used was 34g, ensuring that no animal would be carrying more than 6% of its body weight. Each toad caught was given a unique toe-clip mark (Martof [1953] system) so that it could be individually identified in cases of lost or failed transmitters, or in the event that an animal was recaptured for telemetry purposes in subsequent years.

We attempted to relocate each radio-tagged animal at least once every 3 to 5 days between 8am and 6pm using a Communications Specialists R-1000 telemetry receiver with a Telonics RA-14 antenna. Relocations typically included visual contact unless an animal was in a burrow or very thick vegetation. We avoided disturbing animals that were not readily visible and recorded their locations as accurately as possible (usually within 2m). We recaptured each animal at least once every 15 days for evaluation of waistbelt fit. Weight and SVL were recorded during each recapture. Animals that developed sores from the waistbelts were treated with Bactine® following

recommendations of the USGS, National Wildlife Health Center (D. Earl Greene, ARMI SOP NO. 100; 16 February 2001), 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 animal's last known location in a pattern of roughly concentric circles, increasing the radius by about 200m with each circle. Beginning in late August, animals were recaptured, and their radio tags removed. Animal handling protocol was approved by the University of Montana IACUC (010-04LEFWB-041504).

At each toad location, we recorded a suite of variables including burn severity, UTM's (Garmin GPSmap76), occupied microhabitat type, slope, aspect, distance to water, and transmitter temperature.

ANALYSIS

I used a weighed t-test to assess difference in habitat use by male and female toads. Because no difference was found, I combined all telemetry locations and used a Chi-square test (Neu et al. 1974) to evaluate habitat selection. I compared the number of locations in each burn severity category to the number expected, given the proportional availabilities of each category.

Habitat availability varied by site. I defined available habitat for each site separately as all terrestrial area within a 1km radius centered on the breeding pond(s) where toads were initially marked (Fig. 1). I believe these estimates of availability are conservative considering that Bartelt (2000) documented male western toads traveling up to 439m in a single day, and E. Bull (pers. comm.) recorded single-day movements in excess of 500m. I used ArcMap (ESRI) to calculate areas of each of 3 burn severity categories (i.e., unburned, low to moderate severity, and high severity [Table1]) within each site. I determined the expected numbers of locations by calculating expected numbers in each severity for each site separately, then summing the values for each severity across all 3 sites. Because zero locations were recorded in unburned habitat, I recalculated the chi-square after excluding that category. This recalculation was intended

to test whether the result of the Chi-square was unduly influenced by the unused category.

I calculated Bonferroni 95% simultaneous confidence intervals (Neu et al. 1974; Byers and Steinhorst 1984) for proportions of observations in each site-severity combination to determine whether the results of the Chi-square tests were being dominated by the influence of any one site. Because it yielded more conservative intervals, the z-value was based on all 9 site-severity combinations. Expected proportions were weighted by the number of locations within each site.

RESULTS

Twenty-two toads were radio-tagged (8 at site 1; 7 at each of sites 2 and 3). All radio-tagged toads weighed more than the 34g threshold, and 32% tested positive for chytrid (Table 2); the effects of chytrid were not evaluated here. Three toads were never relocated after their initial captures, and 1 freed itself from its belt. The remaining 18 toads (13 males and 5 females) were nearly evenly distributed across the 3 sites (5 males and 2 females at site 1, 4 males and 2 females at site 2, and 4 males and 1 female at site 3). A total of 167 relocations were recorded. Numbers of observations per toad ranged from 2 to 21 (mean = 9.3; SE = 1.6).

Table 2. Summary of length, weight and chytrid status for all toads radio-tagged in the Robert Burn within Glacier National Park during the summer of 2004.

Sex	# of Toads	<u>Weight (g)</u>		<u>Length (mm)</u>		<u>Chytrid</u>
		Mean	Range	Mean	Range	# positive / # tested
Male	14	71.0	43.5 - 108.7	87.1	73 - 105	3/9
Female	8	105.6	66.0 - 171.2	103.5	92 - 114	4/7

The majority of relocations for both male and female toads were in high severity burns (87 and 74 percent, respectively). The proportion of relocations in high severity burn did not differ by sex (weighted t-test, $p = 0.42$).

The area of each burn severity differed greatly across the sites. Overall, the majority of the area encompassed by the 3 study sites was in the low-moderate severity category. The number of toad relocations was highest in high severity in all sites (Table 3).

Table 3. Areas of 3 burn severity categories and the corresponding numbers of toad relocations recorded in each of 3 study sites in the Robert Burn of 2003.

	Severity	Area (hectares)	Number of Toad Relocations
Site 1	Unburned	11.4	0
	Low-Moderate	53.4	2
	High	157.0	28
Site 2	Unburned	1.3	0
	Low-Moderate	148.3	14
	High	164.2	66
Site 3	Unburned	11.4	0
	Low-Moderate	246.7	25
	High	56.1	32
Combined	Unburned	24.1	0
	Low-Moderate	448.4	41
	High	377.3	126

Toad relocations ($n=167$) were disproportionate across the 3 severity categories (Chi-square = 68.414, $df = 2$, $p < 0.0001$) (Table 4). Excluding the unburned category had very little effect on the level of significance (Chi-square = 62.86, $df = 1$, $p < 0.0001$) but did confirm that the result of the test is driven by the greater-than-expected use of the high severity category.

Table 4. Comparison of observed and expected numbers of western toad relocations in 3 burn severity categories in the Robert Burn of 2003 using a Chi-square test.

Severity	<u>Numbers of relocations</u>	
	Observed	Expected
Unburned	0	4
Low-Moderate	41	90
High	126	73
Chi-square = 68.414, df = 2, P < 0.0001, n = 167		

Observed use of unburned and low-moderate severity were less than expected in all sites. Observed use of high severity was greater than expected in all sites (Table 5). None of the confidence intervals overlapped the expected values, indicating significance at the $\alpha=0.05$ level in all testable cases.

Table 5. Bonferroni 95% confidence intervals for observed proportions of toad locations in each site-severity combination in the Robert Burn of 2003 within Glacier National Park.

	Severity	<u>Proportions of locations</u>		Bonferroni 95% Simultaneous CI
		Observed	Expected	
SITE 1	Unburned	0.000	0.052	***
	Low-Mod	0.067	0.241	$0.01 \leq p \leq 0.12$
	High	0.933	0.708	$0.88 \leq p \leq 0.98$
SITE 2	Unburned	0.000	0.004	***
	Low-Mod	0.175	0.473	$0.09 \leq p \leq 0.26$
	High	0.825	0.523	$0.74 \leq p \leq 0.91$
SITE 3	Unburned	0.000	0.036	***
	Low-Mod	0.439	0.785	$0.33 \leq p \leq 0.55$
	High	0.561	0.178	$0.45 \leq p \leq 0.67$

*** Standard normal confidence intervals cannot be established because zero relocations were recorded.

DISCUSSION

Toads that bred in the Robert burn in the spring of 2003 were found exclusively in burned habitats during the summer months that followed. I found that toads used areas that burned at high severity much more than would be expected given the availability of burn severities across my study area. Selection for the high severity burn category was so strong that concerns about pseudo-replication when using a chi-square test for this type of analysis (Manly et al., 2002) are minimal. The fact that the pattern was consistent for both sexes across all sites lends a great deal of support to my results.

I saw no barriers to prevent toads from accessing any habitat considered available within my study sites. The only feature I expected might inhibit movement was the high severity category that ultimately contained the majority of toad relocations. I do not believe availability of unburned habitat was a limitation, because toads were often found near patches of unburned forest or adjacent to the burn perimeter.

All relocations were during daylight hours. Thus, I cannot evaluate how toads used the landscape at night. While this limits my ability to speculate about activity throughout the 24-hour period, I most expected toads to seek refuge in unburned habitat during the days, thereby reducing evaporative water loss. Surprisingly, no toads were ever found in unburned habitat.

Chytrid was present in the study population, but whether infected animals exhibit differences in habitat selection has not been evaluated. Corn et al. (in prep) are combining the results from this and other studies for a more comprehensive analysis.

The mechanisms driving the positive response of western toads to wildfire have not yet been determined. The use of open areas by toads that I documented is counter to what Bartelt et al. (2004) found in clearcuts in northern Idaho. This contrast may be due to regional variations in climate, unique characteristics of different populations, or differences resulting from the type of disturbance being considered. The length of time since an area burned may also be an important factor in evaluating the benefits of fire for toads. Kirkland et al. (1996) also found toads to be more abundant in areas burned in the previous year than in adjacent unburned areas, while Bull (2006) found that western toads in Oregon did not favor burned over unburned habitat 6 to 9 years after fires.

The fact that the western toad benefits from disturbances in some portions of its range is becoming more apparent (Crisafulli and Hawkins 1998; Pilliod pers. comm.; Hossack et al., in prep). Whether anthropogenic disturbances have equivalent benefits to natural disturbances remains unknown. I found that adult western toads use habitat previously thought far too inhospitable. While my findings add to our knowledge of how adult toads use the landscape following fire, we still cannot explain the post-fire breeding responses documented in Glacier National Park; what effects variability in natural fires may have on such responses also remain unclear.

I found no documentation in the literature of similar breeding responses following prescribed burns. Prescribed burns and fuel reduction by mechanical means may create some similarities in conditions to those resulting from natural fires, but may not be equivalent for toads. As suggested in other systems (Robertson and Ostertag 2004), the effects of prescribed burns on toads may depend on many variables (e.g., type, season, and frequency of burn).

Additional studies of toads and their prey in burned areas may help illuminate the mechanisms at work in these systems. Comparisons of toad growth rates or levels of nocturnal activity in different burn severities could provide useful indices of habitat quality for western toads. Collecting data for such comparisons may prove problematic because toads were so seldom found in unburned habitat in the areas where the post fire breeding responses were documented. Prey availability may play an important role in understanding toad activity following fire. B. Robertson and N. Schwab (pers. comm.) documented increases in abundance of potential prey items including beetles and ants during the summers following other wildfires in this region.

The benefits of wildfire for many species have been well documented (e.g., Black-backed woodpecker [Hutto 1995; Murphy and Lehnhausen 1998], Red-cockaded woodpecker [James et al. 1997], and Jewel beetle [Linsley 1943]). Little is known about the effects of wildfire on amphibians (Bury et al. 2002; Pilliod et al. 2003; Bury 2004) and even less about the effects on the western toad. My results, along with those of concurrent research on toads in Glacier National park (Hossack et al, in prep) provide critical information about responses of a declining species to fire. These findings are remarkable not only because they are for a species of conservation concern, but

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especially because they demonstrate an immediate positive response of an amphibian to fire - not the expected response from a water dependent species. This information is timely for forest management and may prove useful in decisions on fire suppression, fuels reduction, and prescribed burning practices.

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