

Grizzly bear use of pink hedysarum roots following shrubland fire in Banff National Park, Alberta

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Abstract: Hedysarum (*Hedysarum* spp.) roots are a major food for grizzly bears (*Ursus arctos*) over much of their Canadian and Alaskan range. In Banff National Park, grizzly bears typically dig roots of pink hedysarum (*H. alpinum*) in willow (*Salix glauca*, *S. farriae*) – dwarf birch (*Betula glandulosa*) shrubland. This shrubland type often burned in the past, but the effects of shrubland fire on grizzly bear feeding ecology have not been studied. We applied shrubland fire to pink hedysarum digging habitat in Banff National Park and measured grizzly bear response by counting their excavations for pink hedysarum roots over the subsequent 4–6 years. In 4 of 6 study sites, a positive fire effect was recorded: the digging density ratio (digging density in burned habitat divided by digging density in unburned control) increased 4.5x to 14.3x following fire compared to the ratio we recorded in the same treatment and control areas before fire was applied. In the remaining 2 study sites, grizzly bears dug 1 site essentially the same following fire (postfire ratio = 1.1 x prefire ratio), and 1 site showed a weak negative fire effect (postfire ratio = 0.8 x prefire ratio). Overall, fire resulted in >6x increase in the digging density ratio compared to the prefire ratio ($n = 6$ sites). Ease of digging did not appear to be an important factor in our study: the pull required to release a steel bar driven 11 cm into the substrate immediately beside diggings was approximately equal in burned and unburned habitat. The strong preference grizzly bears showed for excavating pink hedysarum roots in burned habitat suggests that shrubland fire may benefit grizzly bears in Banff National Park and perhaps elsewhere in North America where comparable digging habitat occurs.

Key words: Banff National Park, *Betula glandulosa*, digging, dwarf birch, fire, grizzly bear, habitat, *Hedysarum alpinum*, *Salix*, *Ursus arctos*, willow

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The North American grizzly bear (*Ursus arctos*) has been described as an animal of open habitat (Herrero 1972) and has exhibited positive associations with the shrubland and grassland that often follows stand-removing forest fire (reviewed in Hamer and Herrero 1987a). The effects of forest fire on the feeding ecology of grizzly bears in Banff National Park (NP) have been studied for 2 major foods, fruits of buffaloberry (*Shepherdia canadensis*) and roots of yellow hedysarum (*Hedysarum sulphurescens*). Buffaloberry fruit production was high in open habitat (including habitat subject to prescribed fire and wildfire), low in sites under closed forest canopy, and

in significant decline in those portions of a 25-year-old burn where a lodgepole pine (*Pinus contorta*) canopy was re-establishing quickly postfire (Hamer 1996). In yellow hedysarum habitat, prescribed forest fire led to intensive digging by grizzly bears within 10 years of fire, whereas adjacent, unburned forest was undug (Hamer 1999).

Roots of pink hedysarum (*H. alpinum*) also are an important food for grizzly bears in Banff NP (Hamer and Herrero 1987b) and elsewhere in Canada (Pearson 1975, Russell et al. 1979) and Alaska (Murie 1981, Phillips 1987). Roots of pink hedysarum usually are smaller in diameter and shorter than those of yellow hedysarum, in part possibly because they often grow in moister soil with a seasonally high water table. The fleshy tap roots typically are 10–20 cm long, occasionally much longer (particularly when growing in well drained or gravelly

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soil), and up to 1.5 cm in diameter (Murie 1944; D. Hamer, personal observations). Murie (1981) detailed typical grizzly bear use of these roots. Pink hedysarum resprouts readily from its tap root following either low-severity fire or incomplete excavation by grizzly bears.

In Banff NP, grizzly bears generally dig pink hedysarum roots in willow (*Salix glauca*, *S. farriae*)–dwarf birch (*Betula glandulosa*) shrubland openings in the lower subalpine zone (Hamer 1985); diggings for pink hedysarum roots are rarely found in closed-canopy forest. The communities in Banff NP where pink hedysarum is dug include (1) successional mature shrubland (valley bottom sites where trees are sparse because of cold air pooling or seasonally high water table); and (2) seral shrubland (mesic openings within the lower subalpine forest that can develop and in some cases persist for many decades following forest fire) (Corns and Achuff 1982; Hamer 1985; Hamer and Herrero 1987a,b).

Willow–dwarf birch shrubland on the East Slopes of the Canadian Rockies likely burned frequently prior to the 1900s. Evidence from fire-scarred trees near meadows suggests that from 1900–50, fire activity declined sharply, but that prior to 1900, mean fire return intervals varied from 20–60 years (White et al. 2002). These shrublands burn intensely, largely due to the resinous twigs of dwarf birch (deGroot 1998). However, the effects of shrubland fire on grizzly bear feeding ecology have not been studied. Such information is important given the link between food availability and bear reproduction (Robbins et al. 2004) and because grizzly bears in the Bow Valley watershed, of which Banff NP is a major jurisdiction, are the slowest-reproducing grizzly bear population reported in the literature. Adult females in this region have low body mass, high age of first reproduction, and a long interval between litters (Garshelis et al. 2005, Herrero 2005). Thus, changes in their environment, such as shrubland fire, that have the potential to affect the quality, quantity, or availability of natural plant foods may be important to the productivity and long-term survival of this bear population.

Our objective was to measure the effect of shrubland fire on grizzly bear use of pink hedysarum roots in Banff NP. We created mosaics of burned and unburned shrubland in known pink hedysarum digging habitat and studied these sites over the next 4–6 years to address the question: Will grizzly bears use burned and unburned habitat with equal intensity when excavating pink hedysarum roots?

Study area

Our study area was in the Front Ranges of Banff NP, east of the Main Ranges of the Rocky Mountains, and thus in a rain shadow with respect to the prevailing westerly weather. The Front Ranges also are subject to strong, drying chinook (foehn) winds. Annual precipitation is about 500–750 mm (Janz and Storr 1977).

The study area contained 2 major drainages, the Panther and Cascade valleys. The lower slope and valley bottom shrubland was dominated by dwarf birch, white willow (*S. glauca*), and, in moister sites, *S. farriae*. Comparable community types were described by Corns and Achuff (1982; types O18, S1, S4, S9–S12). Scattered groves of spruce (*Picea engelmannii* × *P. glauca*) and occasionally lodgepole pine typically occurred within 20–100 m of our study plots. Soils were fine textured with abundant organic matter. Alluvial gravels or other coarse fragments did not occur within the depth dug by bears.

We studied 3 sites in the Panther Valley and 3 sites in the Cascade Valley. In each valley, the sites were named Downstream, Midstream, and Upstream with reference to their relative locations. All sites were within 10–250 m of a river. The 3 Panther sites were approximately 1.5 km apart along a 3-km reach of the river. They were on level terrain 2–10 m above the river and 1,850–1,900 m elevation, and were in successional mature shrubland.

The 3 Cascade sites were 15–20 km south of the Panther sites. The Downstream Cascade site was successional mature shrubland on level terrain, approximately 5 m above the river at 1,670 m elevation. The Upstream and Midstream Cascade sites were located in seral shrubland 5 and 7 km up-valley of the Downstream site, respectively. These 2 sites were on gentle, northeast-facing slopes 1,740 and 1,800 m elevation and 20–40 m above the river. The slopes adjacent to these 2 sites rise up into the Vermilion Range, which quickly ascends to 2,900 m elevation to the southwest, thus shading and sheltering these sites from the sun and chinook winds. These slopes were a mosaic of seral shrubland and trees regenerating from a 1936 fire (White 1985) that burned through mature spruce forest during a severe drought, leaving few surviving trees; this lack of seed, and perhaps cool site conditions, evidently contributed to the slow re-growth of trees into portions of this burn.

All study sites were in roadless backcountry. The Cascade Downstream site was closest to the nearest road (15 km).

Table 1. Plot sizes and locations, Panther and Cascade valleys, 1999–2005, for a study of grizzly bear use of pink hedysarum roots following shrubland fire in Banff National Park, Alberta, Canada.

Valley	Site	n	Mean plot size, m ² (range)	
			Treatment	Control
Panther	Upstream	4	394 (260–552)	369 (174–549)
	Midstream	4	315 (208–390)	393 (131–531)
	Downstream	2	862 (365, 1359)	398 (134, 623)
Cascade	Upstream	5	293 (208–481)	301 (208–481)
	Midstream	3	382 (186–587)	384 (320–458)
	Downstream	2	562 (540, 584)	586 (540, 632)

Methods

Study site layout

We chose the 6 study sites from relatively extensive shrubland occurring along central portions of the Panther and Cascade valleys according to 2 criteria: (1) sufficient area of continuous shrubland to allow us to establish a mosaic of burned and unburned plots using prescribed fire; and (2) presence of diggings by grizzly bears for pink hedysarum roots (thus, plots were established in known grizzly bear digging habitat). Within each site we established pairs of rectangular plots parallel to the river (4 sites) or up the fall line (2 sites). We placed each pair of plots within conterminous digging habitat that contained similar features (slope angle, shrub density, community structure, degree of hummocking, located on same terrace). Thus, plot size ($\bar{x} = 420 \text{ m}^2$) varied considerably to conform with available homogeneous habitat (Table 1). The distance between adjacent plots usually was 0–12 m. We avoided microhabitat such as the edges of terraces, toes of slopes, and wildlife trails (where grizzly bear diggings were often abundant) because these areas were too small to provide experimental plots. We assigned plots to treatment (to be burned) or to control (fire to be excluded) in alternation across the site. The number of pairs of plots in each site (Table 1) reflected the extent of available digging habitat.

Fire

Fire was applied as part of the prescribed fire program in Banff NP. The park management plan calls for burning an average of 1,400 ha/yr (Parks Canada 1997).

In the Panther Valley, we used pumps and hoses to soak the control plots with river water prior to ignition. The sites were burned on 25–26 May 1999. The fire spread readily and burned 200 ha of shrubland, with flame heights of 2–4 m; 300 ha of adjacent forest also

burned. In the Cascade Valley, fire hazard was lower, and fire was controlled with ignition pattern, previously burned guards, wildlife trails, and backpack water bags. We tried to burn the Upstream site in October 1998 and again on 27 May 1999, but because the site was sheltered by the Vermilion Range (see Study area), the site was too cool and wet. On 7 June 2000, we burned the Upstream and Midstream sites but because the fire did not carry well, portable propane torches were used a week later to achieve further treatment, including top-kill of shrubs. In the Cascade Downstream site, we burned the plot edges in September 2000. On 12 May 2001, the treatment plots and some adjacent shrubland were burned successfully with flame heights of 1–1.5 meters.

Because the Panther burn occurred under ideal burning conditions, the plots generally were surrounded by burned vegetation (after fire, unburned plots were islands of green vegetation, with fire stopping near the boundaries of these control plots). In the Cascade, the converse occurred because of poor burning conditions (fire was mostly confined to the burned plots and their immediate surrounds).

Site analysis

We counted prefire diggings by grizzly bears for pink hedysarum roots to establish a baseline for the treatment and control plots. Hedysarum diggings probably remain conspicuous for at least 3–5 years (Murie 1981, D. Hamer, personal observations); thus, pre-treatment data include several years of grizzly bear digging activity (we did not document the exact number of years). Excavated soil or sod from diggings was smoothed out or removed during data collection.

We counted postfire diggings by grizzly bears for pink hedysarum roots on treatment and control plots each summer for 4 years (Cascade Downstream), 5 years (other Cascade), or 6 years (Panther) following burning. We identified new (previously uncounted) diggings by the presence of excavated soil or sod, which we smoothed out or removed so that diggings would not be recounted in subsequent years.

We measured total shrub cover and height of willow and dwarf birch along linear transects in treatment and control plots. At each 2-pace interval we measured height (cm) as the length (burned habitat) or vertical projection (unburned control) of the longest or tallest living shoot within 30 cm of the paced location. If no shoots occurred in this zone, we used a closest-plant method (Hamer 1996) to locate the next shoot to be

measured. The vertical projection was the vertical distance between the tip of the tallest shoot and ground level. We measured length in burned habitat because of the small size and recumbent growth of many resprouting shrubs. Use of length was conservative because for recumbent shrubs this measurement was greater than vertical projection measurements; use of the smaller measurement could exaggerate the apparent difference in shoot regrowth between the small, recumbent stage and later, taller stages of shrub regrowth. A mean of 94 (47 willow and 47 dwarf birch) shrub heights was measured at each site for each habitat category (burned [1 year postfire], burned [3–5 years postfire], unburned). We reported median values to reduce the effect of extremes (shoots browsed by ungulates or shoots unburned within a burned plot). We used the line intercept method to estimate total shrub cover (mean total intercept length, 142 m/site for each habitat category [burned, unburned]).

We assessed ease of digging by recording the force required to release a 2.8-cm wide steel bar hammered 11 cm vertically into the ground beside diggings made by grizzly bears (details provided by Hamer 1999). An 8-rope block-and-tackle was attached and the force (directed parallel to the ground) required to release the bar was measured using a maximum pull of 32 kg. Because of the 32-kg upper limit, we used medians for analysis. We measured ease of digging at a minimum of 60 diggings in each site (30 in burn, 30 in control) except for the Panther Upstream site (40 diggings measured) and the Panther Downstream site (deleted because of insufficient grizzly bear diggings in unburned habitat). We took 2 measurements at each digging, approximately 12 cm right and 12 cm left of the excavation. At this 12-cm distance, excavations did not appear to weaken the undisturbed substrate being tested, but we assumed that it was sufficiently close to assess the ease of digging bears encountered when excavating hedysarum roots. Ease of digging measurements were made in the last year of the study (6 years postfire in the Panther; 4 years postfire in the Downstream Cascade site; 5 years postfire in the other Cascade sites).

Data analysis

Sites were our experimental units. (Plots within each study site were not independent.) Because of small sample size ($n = 6$ sites), we did not use statistical hypothesis testing and we did not model the effects of valley, year, fire intensity, and other potentially intervening variables on grizzly bear digging activity.

At each site, we totalled the number of pink hedysarum excavations in treatment and control plots, separately for pre- and postfire periods, to calculate 4 digging densities (diggings/100 m²): prefire (treatment and control) and postfire (treatment and control). We collapsed all annual, postfire counts at each site into these 2 postfire totals because in some sites in some years, grizzly bears dug very few or even zero roots (particularly in control habitat).

At each site, we assumed that the difference in the prefire digging densities between habitat assigned to treatment and habitat assigned to control reflected grizzly bear selection for microsite heterogeneity that we did not recognize when we established our purportedly matched pairs. We therefore used prefire data as the baseline against which to compare postfire results. At each site, we quantified this baseline using a ratio calculated from prefire data, where the ratio = digging density in habitat assigned treatment/digging density in habitat assigned control. For each site, we calculated the comparable ratio for postfire data, where the ratio = digging density in burned habitat/digging density in control. We then calculated a response ratio by dividing the postfire ratio by the prefire ratio. If this response ratio was >1 , we postulated a positive fire effect.

To analyze our data on an annual basis, we conceptualized our study as series of trials, each of 1-year duration and conducted in each study site, where bears excavating pink hedysarum roots would present 1 of 2 possible outcomes: either greater density (+) or lower density (–) of diggings in burned versus control habitat. We assumed that these 1-year intervals were sufficient to generate independent samples. The nominal scale (+, –) accommodated our data given that many of our annual data points were zeros, resulting from times when grizzly bears did not dig 1 or both habitat categories (burned, unburned) in a study site during that 1-year interval. We again used prefire ratios as our baseline; that is, an annual trial scored + if the postfire ratio of burned to control digging densities exceeded the prefire ratio of treatment to control digging densities at that site.

Results

Fire reduced shrub height and cover, likely for the duration of our study (Table 2). Willow and dwarf birch shrubs in the Panther sites showed an increase in height across the 3 measured stages of 1 year postfire, 5 years postfire, and unburned. Five years (Panther) or 4 years

Table 2. Median shrub height and total shrub cover in burned and control habitat in the Panther and Cascade valleys, Banff National Park, Alberta, Canada, 2000–2004.

Site ^a	Willow height (cm)			Dwarf birch height (cm)			Total shrub cover (%)	
	1 year postfire	3–5 years postfire ^b	Unburned control	1 year postfire	3–5 years postfire ^b	Unburned Control	3–5 years postfire ^b	Unburned control
UP	28	38	91	14	40	95	51	89
MP	17	25	30	14	36	65	51	55
DP	35	54	97	17	45	101	53	53
UC		26	48		34	78	38	56
MC		38	72		34	78	44	56
DC		45	91		41	95	45	69
Mean		38	71		38	85	47	63
SD		11	27		4	14	6	14

^aU = Upstream site; M = Midstream site; D = Downstream site; P = Panther; C = Cascade.

^bFive years postfire in the Panther and 4 years postfire in the Cascade study sites (3 years in the Cascade Downstream site).

(Cascade) after fire, shrub height was approximately half that of shrubs in unburned plots, and total shrub cover in 5 of the 6 sites averaged roughly 20% less in burned habitat (Table 2). Our measurements of grizzly bear digging activity extended 1 year beyond our last shrub measurements, but we do not expect that shrub parameters would have changed substantially during the additional year.

Grizzly bears showed a clear preference for digging pink *hedysarum* roots in burned shrubland in 4 of our 6 study sites. Postfire/prefire digging density ratios at these 4 sites varied from 4.5–14.3, indicating high use of burned versus unburned control habitat compared to the relative use of these same areas before fire (Table 3). Of the remaining 2 sites, we interpreted grizzly bear

response to fire in the Cascade Midstream site as neutral (1.1 postfire/prefire ratio indicating a modest 10% increase in relative use of burned habitat compared to prefire use), and a weak negative response to fire in the Cascade Downstream site (0.8 postfire/prefire ratio indicating a 20% decrease in relative use of burned habitat compared to prefire use). Overall, fire resulted in a >6X increase in the digging density ratio compared to the prefire ratio of use ($n = 6$ sites), suggesting a preference by grizzly bears to dig pink *hedysarum* roots in shrubland after it has been burned (Table 3). Bears dug burned habitat especially heavily in the Panther Downstream and Cascade Upstream sites, with 19–21 diggings/100 m² in burned habitat versus 0–2 diggings/100 m² in control habitat (Table 3).

Table 3. Digging densities (diggings/100 m²) and digging density ratios (treatment [burned] divided by control [unburned]) calculated from numbers of excavations by grizzly bears for pink *hedysarum* roots in Banff National Park, Alberta, Canada, 1999–2005. The postfire/prefire ratio is calculated from the respective digging density ratios; a postfire/prefire ratio >1 shows greater digging activity in burned than control habitat following fire compared to the relative use of these treatment vs. control areas before fire. Numbers in parentheses indicate the range of annual values that were summed to obtain the postfire densities.

Site ^a	Years of data	Prefire			Postfire			Postfire/prefire ratio
		Diggings/100 m ²		Digging density ratio	Diggings/100 m ²		Digging density ratio	
		Treatment (to be burned)	Control		Treatment (range)	Control (range)		
UP	6	0.38	1.36	0.28	22.14 (0–10.6)	8.74 (0–5.5)	2.53	9.0
MP	6	8.08	14.07	0.57	22.66 (0.8–13.9)	8.78 (0.7–3.1)	2.58	4.5
DP	6	2.55	0.92	2.77	19.43 (0–11.7)	0	>19.4	>7.0
UC	5	0.89	1.33	0.67	21.71 (0–17.3)	2.26 (0–1.3)	9.61	14.3
MC	5	5.06	13.80	0.37	7.85 (0–5.4)	19.79 (0–8.9)	0.40	1.1
DC	4	15.93	8.53	1.87	26.60 (5.2–7.5)	18.60 (0.7–7.3)	1.37	0.8
Mean								5.9 ^b
SD								5.7 ^b

^aU = Upstream site; M = Midstream site; D = Downstream site; P = Panther; C = Cascade.

^bPanther Downstream site omitted from mean and SD calculations; the mean is >6.1 if this site is included.

Grizzly bears that responded to fire in the Panther study sites did so rapidly. In the year following fire, postfire/prefire ratios of 12.6 and 17.2 were recorded, indicating very high use of burned habitat compared to relative use of these areas before fire. The ratio for the third site could not be calculated because of a zero data point in the Downstream control site; however, we recorded 11.7 and 0.0 diggings/100 m² in the burned and control portions of this site, respectively, the year following fire. In the Cascade Valley, results in the year following fire were unlike those from the Panther, with less use in burned habitat (mean postfire/prefire ratio = 0.40, SD = 0.06, *n* = 3). This result suggests a possible lag in fire response in the Cascade sites. If the Cascade ratios are recalculated with the first year of postfire data deleted, the new response ratios are 20.2, 1.7, and 1.0 for the Up-, Mid-, and Downstream sites, respectively, with none of the 3 sites indicating a negative response to fire after the first year. Fire effects evidently persisted for the duration of our study. In the last year of data collection, we recorded postfire/prefire ratios of 16.9 and 19.5 in 2 sites.

When we analyzed the data on an annual basis, with each 1-year interval at each study site conceptualized as a trial where grizzly bears could dig more (+) or less (-) intensely in burned habitat, the Panther's burned habitat had greater digging intensity in 14 of 15 trials, whereas burned and unburned habitat in the Cascade Valley scored approximately equally with 7 of 12 outcomes in favor of burned habitat (Table 4). All dug annual samples differed by ≥13%, so we judged all trials as showing preference for either burned or control habitat. Overall, grizzly bears showed a preference for burned habitat, with 21 versus 6 outcomes in favor of burned habitat.

Ease of digging measurements were essentially equal in both burned and control habitat. The force required to release the bar from the substrate adjacent to root excavations was approximately 17.8 kg (95% CI = 16.2–19.3, *n* = 5) in burned habitat versus 17.3 kg (95% CI = 15.9–18.7, *n* = 5) in control. Results from the 2 sites in seral shrubland (both 17.8 kg in burned habitat; both 17.4 kg in control) were similar to the 3 sites in mature shrubland (17.8 kg [range, 16.5–19.8 kg] in burned; 17.2 kg [range, 15.8–18.9 kg] in control).

Discussion

Our results indicate that grizzly bears responded positively to shrubland fire when digging pink hedysarum roots in the 3 Panther sites and in 1 of the Cascade

Table 4. Number of years in each study site when the ratio of digging density in burned habitat to digging density in unburned control habitat was greater (+) or less (-) than the prefire ratio at that site, where digging density was calculated from the number excavations by grizzly bears for pink hedysarum roots in Banff National Park, Alberta, Canada, 1999–2005.

Valley	Site	Number of years digging density was		
		>1 (+)	<1 (-)	0 ^a
Panther ^b	Upstream	5		1
	Midstream	5	1	
	Downstream	4		2
	All dug annual samples	14	1	—
Cascade ^c	Upstream	3	1	1
	Midstream	2	2	1
	Downstream	2	2	
	All dug annual samples	7	5	—
All sites	All dug annual samples	21	6	—

^aYear with zero diggings in both burned and control habitat.

^b6 years of annual samples in the Panther Valley.

^c5 years of annual samples in the Cascade Valley (4 years in Downstream site).

sites. In the remaining 2 Cascade sites, grizzly bears showed a somewhat neutral response. We have limited data on potentially intervening variables such as fire characteristics (intensity, severity, size, season), community structure, or characteristics of pink hedysarum roots (size, density, digability, nutrient content and digestibility) that could allow explanatory analyses of shrubland fire's effects on grizzly bear use of pink hedysarum digging habitat. For example, fire in the Cascade sites was less severe and covered less area around the study plots than in the Panther sites, but given our small sample size we cannot validly speculate on possible effects of such variables. Rather, we recommend that future research address how environmental factors, of which fire is but 1, affect grizzly bear selection of the pink hedysarum roots they choose to excavate.

The somewhat neutral response shown by grizzly bears to shrubland fire at the Cascade Midstream and Downstream sites may partly reflect a time lag. If the data from the first year of postfire digging are deleted (when the mean response ratio for the Cascade sites, 0.40, showed grizzly bear preference for unburned habitat in the year following fire; see Results), the response ratios at these 2 sites move from 1.1 and 0.8, to 1.7 and 1.0. Thus, at 1 of these 2 sites, grizzly bears showed a delayed, positive response to fire. However,

caution is necessary when interpreting such *post hoc* analysis of limited data.

Ease of digging commonly distinguishes dug from undug grizzly bear feeding habitat (Holcroft and Herrero 1984, Mattson 1997, Hamer 1999). In our study, ease-of-digging measurements were essentially the same in burned and control habitat. The prescribed fires killed only the shoots of willow and dwarf birch; the roots remained alive and supported the regeneration of new shoots a few weeks after fire. Thus, unlike in coniferous forest (Hamer 1999), we did not anticipate that digging would become easier as fire-killed roots decomposed. Although our ease-of-digging measurements suggested that fire did not affect handling time (i.e., digging effort), fire may have affected searching time. We found it much easier to move through the shorter, lower-density shrubs of the burned sites, and bears attempting to locate profitable roots and maximize energy intake may have found the same.

Digging densities in our study sites varied widely from year to year, as expected. Grizzly bear use of pink hedysarum roots can vary in response to such factors as the spatial distribution of bears or annual variations in food availability (for example, in years of high fruit production, roots can become a minor autumn food; Pearson 1975, Russell et al. 1979, Murie 1981, Hamer and Herrero 1987b). However, such annual differences should not confound our study. We assume that whether bears dug heavily or lightly, we would still record their relative preferences for burned versus unburned habitat over the measured time interval.

Relative values (such as our digging density ratios) can be misleading, particularly if either the numerator or denominator of such a ratio is a small number subject to sampling error. However, our digging density ratios were derived from relatively large counting efforts. First, our data were analyzed by site, not by the smaller unit of plots within sites. Second, postfire ratios were derived from total counts, where data from all years of postfire study were collapsed into single values. Third, prefire counts, although done only once at each site, also tallied several years of feeding activity because excavations made by grizzly bears for pink hedysarum roots remain conspicuous for several years. Thus, we believe that our relative digging ratios are a reasonably robust measure of grizzly bear preferences for burned vs. unburned habitat in our 6 sites.

If grizzly bears were to excavate a significant portion of available roots, this could confound our study given that we monitored sites over multiple years. Murie (1981: 136) observed, for example, that grizzly bears in

Denali National Park sometimes dug so intensively that some areas “resemble plowed fields.” He suggested that bears may have sufficiently depleted some pink hedysarum digging areas to cause their neglect for a year or longer. In our study area, however, diggings generally were scattered, not contiguous, and bears appeared to remove only a fraction of available roots. In a small assessment of pink hedysarum shoot density (which likely is an index to root density; see Hamer 1999), similar densities occurred in both burned and control habitat (pink hedysarum density 4–5 years postfire: burned: 7.5 shoots/m², SD = 6.1; *n* = 164 shoots tallied; control: 7.2 shoots/m², SD = 5.4; *n* = 90 shoots tallied; D. Hamer, unpublished data).

Our study had small sample size and several confounding variables, including 2 major valleys, 2 shrubland types (seral upland and mature valley bottom shrubland), differing fire intensity and size, and other site conditions. The difficulty of implementing experimental studies in a wilderness environment precluded more extensive research. We had difficulty achieving ignition and fire spread in 2 of the 3 Cascade study sites, and, in contrast, park staff used substantial resources to ensure that the high-intensity Panther fire did not burn beyond the park boundary. Nevertheless, we recommend further research regarding shrubland fire’s effects on grizzly bear habitat in the Canadian Rocky Mountains. Given that grizzly bears, at least in Banff NP and surrounds, are the slowest-reproducing population studied in North America (Garshelis et al. 2005) the potential influence of shrubland fire on the quality, quantity, and availability of natural plant foods should be understood. The strong preference we recorded for grizzly bears to excavate pink hedysarum roots in the burned habitat of 4 of our 6 sites, coupled with the essentially neutral fire-effect in the remaining 2 sites, suggests that shrubland fire may benefit grizzly bears in Banff NP and perhaps elsewhere in North America where comparable digging habitat occurs.

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