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**SUPPLEMENTAL MATERIAL**

**Running Head:** Recreational restrictions to reduce bear attacks

**Title:** Potential for recreational restrictions to reduce grizzly bear–caused human injuries

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**SUPPLEMENTAL MATERIAL**

**Text S1**

 We evaluated relative grizzly bear (*Ursus arctos*) densities in Hayden Valley using an index developed by Bjornlie et al. (2014). The index used capture, telemetry, and life-history data from 870 grizzly bears involved in >1,800 captures during 1975–2012 in the Greater Yellowstone Ecosystem (GYE) and spatially reconstructed a lifetime activity range estimate for each individual bear. Bjornlie et al. (2014) then overlaid ranges on a grid of 960, 14- × 14- km cells. For each grid cell, the density index in a given year was the sum of the proportional overlap of all ranges for bears present during that year. Indices were derived for each cell annually during 1983–2012. We averaged grid cell values across all years to evaluate the density index estimates for Hayden Valley relative to other portions of the GYE.

 Hayden Valley includes portions of 2 grid cells (462 and 463). Density index values averaged across all years (1983–2012) for the 2 cells that included portions of Hayden Valley were 20.77 and 18.83. Both values exceeded the 99th percentile (i.e., 18.82; Table S1) among non-zero grid cell averages (Fig. S1). Hayden Valley index values were nearly double the average (10.98) of the 3 cells that included the Lamar River Valley (Fig. S1).

**Table S1. Upper percentile for non-zero grizzly bear density index values in the Greater Yellowstone Ecosystem averaged for year 1983–2012.**

|  |  |  |
| --- | --- | --- |
| *N* | Valid | 315 |
| *N* | Missing | 0 |
| Mean | 5.173 |
| Median | 3.411 |
| SD | 5.440 |
| Min. | 0.00 |
| Max. | 20.77 |
| Percentiles | 95.0 | 16.246 |
| 97.5 | 17.919 |
| 99.0 | 18.817 |

**Fig. S1. Average grizzly bear density index values for grid cell in Hayden Valley, Yellowstone National Park (YNP); Lamar Valley, YNP; and other portions of the Greater Yellowstone Ecosystem for the period 1983–2012.**



**Text S2**

 We conducted a retrospective evaluation of the potential efficacy of closing Hayden Valley in Yellowstone National Park (YNP) to recreational activity during 22 different time periods that coincide with the peak seasons during which grizzly bears consume a variety of foods found in the valley, to determine which closures would be most effective at reducing the frequency of bear attacks in the area.

***Closure for seasonal scavenging of wolf-killed non-neonate elk carcasses***

 Gray wolves (*Canis lupus*) were extirpated from YNP in the mid-1930s, then reintroduced into the park from 1995 to 1996 (Phillips and Smith 1997). In 2000, a wolf pack established a territory in Hayden Valley for the first time (D. Stahler, YNP, Wolf Project, personal communication). Since that time, wolf-killed elk (*Cervus canadensis*) carcasses have been observed in Hayden Valley. The majority of these elk were killed by wolves in March (Metz et al. 2012). A seasonal closure of Hayden Valley during the peak period wolf-killed elk carcasses are available for bears to scavenge would not have prevented any of the 10 grizzly bear–inflicted human injuries that occurred in the valley from 1970 to 2017. There is very little chance of bear-inflicted human injury in Hayden Valley in March because there is very little visitor recreational activity in Hayden Valley during that month. The road through Hayden Valley does not open to the public until early May.

***Closure for seasonal scavenging of wolf-killed non-neonate bison carcasses***

Following establishment of wolves in Hayden Valley, wolf-killed bison (*Bison bison*) carcasses have become available for bears to scavenge. The majority of bison are killed by wolves from 1 March to 15 April. A seasonal closure of Hayden Valley during the peak period during which wolf-killed bison carcasses are available for bears to scavenge (1 Mar through 15 Apr) likely would not have prevented any of the 10 grizzly bear–inflicted human injuries that occurred in the valley from 1970 to 2017. There is very little chance of bear-inflicted human injury in Hayden Valley between 1 March and 15 April because there is very little visitor recreational activity in Hayden Valley during that time period. The road through Hayden Valley does not open to the public until early May. Even after the road opens, the depth of accumulated snow and wet muddy conditions associated with spring snow melt limit visitor recreational activity in Hayden Valley until the area dries out later in June or July. Thus, an early spring season closure during the peak period in which grizzly bears scavenge wolf-killed bison carcasses likely would not be effective at reducing the number of bear attacks in Hayden Valley.

***Closure for seasonal scavenging of winter-killed bison carcasses***

Winter-killed bison carcasses are a highly preferred grizzly bear food that can attract and hold large numbers of grizzly bears to a relatively small area, increasing the probability of hikers having surprise encounters with bears. Each year some solitary adult male bison, as well as small male groups, overwinter in Hayden Valley (Meagher 1973). In addition, mixed herd groups consisting of adult females, 2-year-olds, yearlings, and some mature males move through Hayden Valley in winter on their way to the Firehole River area. Some of these bison die in Hayden Valley each winter. As grizzly bears begin to emerge from hibernation in early March, they seek out and scavenge these winter-killed bison carcasses. The peak season during which grizzly bears scavenge winter-killed bison carcasses is from 15 March to 15 April (Meagher 1973, Green et al. 1997). A seasonal closure of Hayden Valley during the peak period bears scavenge winter-killed bison carcasses (15 Mar–15 Apr) would not have prevented any of the 10 grizzly bear–inflicted human injuries that occurred in the valley from 1970 to 2017. There is very little chance of bear-inflicted human injury in Hayden Valley between 15 March and 15 April because there is very little visitor recreational activity in Hayden Valley during that period. The road through Hayden Valley does not open to the public until early May.

***Closure for seasonal predation on meadow voles***

Meadow voles (*Microtus pennsylvanicus*) periodically occur at high population numbers (Craighead et al. 1995) and can be a significant food for grizzly bears in Hayden Valley (Mealey 1975, Graham 1978). Meadow voles are especially vulnerable to bear predation as snow recedes in spring (Craighead et al. 1995). Consumption of meadow voles is greatest from April to May (Mattson et al. 1991, Mattson 2004a). Had a seasonal closure been in effect in Hayden Valley from 1970 to 2017 during the peak period of meadow vole consumption (1 Apr–31 May), it potentially would have prevented only 1 of the 10 (10%) grizzly bear–inflicted human injuries that occurred in Hayden over the past 47 years. A closure of Hayden Valley during the peak period of meadow vole consumption would not likely be effective at reducing grizzly bear–inflicted human injuries in the valley.

***Closure for seasonal predation on pocket gophers and kleptoparasitism of pocket gopher food caches***

Northern pocket gophers (*Thomomys talpoides*) and their food caches—consisting primarily of onion-grass bulbs (*Melica spectabilis*), yampa roots (*Perideridia gairdneri*), springbeauty (*Claytonia lanceolata*) tubors, and American bistort (*Bistorta* *bistortoides*) rhizomes—are a significant spring food resource for grizzly bears in Hayden Valley (Graham 1978). Consumption of northern pocket gophers and their food caches is greatest from April to May (Mattson 2004b). Had a seasonal closure been in effect in Hayden Valley during the period of greatest pocket gopher consumption (1 Apr–31 May) from 1970 to 2017, it potentially would have prevented only 1 of the 10 (10%) grizzly bear–inflicted human injuries that occurred in Hayden over the past 47 years. Therefore, there is not a compelling case for closing Hayden Valley during the peak period of consumption of pocket gophers and their food caches.

***Closure for seasonal grazing on graminoid foliage***

Grasses (*Agropyron caninum,* *Bromus carinatus,* *Deschampsia cespitosa,* *Melica spectabilis, Phleum alpinum*) and sedges (*Carex* spp.) comprise a large proportion of grizzly bear scats collected in Hayden Valley (Graham 1978). Grizzlies are relatively inefficient grazers because of their dentition and digestive structure (Mealey 1975). Therefore grizzlies graze grasses and sedges primarily during the early growing season when they are succulent and most digestible. The peak period during which grizzlies graze graminoids is from April to June (Mattson et al. 1991). Consumption of graminoids later in summer is restricted to moist sites in small forest openings, forest edges, and the edges of streams and ponds. Had a seasonal closure been in effect in Hayden Valley during the peak period in which bears graze graminoids (1 Apr–30 Jun 30) from 1970 to 2017, it potentially would have prevented only 2 of the 10 (20%) grizzly bear–inflicted human injuries that occurred in Hayden over the past 47 years. Graminoids are relatively abundant and widespread throughout Hayden Valley and YNP, and therefore not subjected to directed grizzly foraging activity. A recreational closure of Hayden Valley during the peak period in which grizzlies graze graminoids would not be very effective at reducing bear attacks in the valley.

***Closure for seasonal predation on bison calves***

Grizzly bears in YNP occasionally prey on neonate bison (Varley and Gunther 2002). The peak period of bison calving occurs from late April through May; however, the birthing period is extended following winters with deep snow and later emergence of spring vegetation (Geremia et al. 2015). Grizzly bear predation on bison calves has been observed as late as 26 June (Varley and Gunther 2002). Had a seasonal closure been in effect in Hayden Valley during the bison calving season (21 Apr–30 Jun) from 1970 to 2017, it potentially would have prevented only 2 of the 10 (20%) grizzly bear–inflicted human injuries that occurred in Hayden Valley.

***Closure for seasonal predation on elk calves***

Grizzly bears in YNP are efficient predators of newborn elk calves from mid-May through mid-June (Gunther and Renkin 1990, Barber-Meyer et al. 2008). Elk that summer in Hayden Valley migrate to the area from the northern winter range. These elk calve both in Hayden Valley and along migration routes to the valley. The annual spring elk migration to Hayden Valley can vary by several weeks depending on winter severity, spring snowmelt, and vegetation green-up. Closing Hayden Valley during the peak of the elk calving season could reduce the chances of hikers having surprise encounters with bears while they are concentrated in calving grounds hunting elk calves or feeding on elk calf carcasses. Had a seasonal closure been in effect in Hayden Valley during the peak elk calving season (15 May–15 Jun) from 1970 to 2017, it potentially would have prevented only 1 of the 10 (10%) grizzly bear–inflicted human injuries that occurred in Hayden over the past 47 years. Although elk calves are a concentrated source of calories, they are generally consumed in just 1 or 2 feeding bouts immediately after predation (Gunther and Renkin 1990). Predation by grizzly bears on neonate elk does not attract and hold multiple bears for long periods of time, so it is less likely to lead to human–bear encounters than larger carcasses. A closure of Hayden Valley during the elk calving season likely would not be effective at reducing grizzly bear–inflicted human injuries in the valley.

***Closure for seasonal grazing on horsetail***

Graham (1978) reported horsetail (*Equisetum* spp.) in grizzly bear scats collected from Hayden and Pelican valleys. The peak period during which grizzly bears consume horsetail in the GYE is from June to July (Mattson et al. 1991). Had a seasonal closure been in effect in Hayden Valley from 1970 to 2017 during the peak period in which grizzlies consume horsetail (1 Jun–31 Jul), it potentially would have prevented 4 of the 10 (40%) grizzly bear attacks that occurred in Hayden over the past 47 years. A closure of Hayden Valley during the peak period in which grizzly bears graze horsetail likely would not be very effective at reducing grizzly bear attacks in the valley.

***Closure for seasonal digging of biscuitroot roots***

On 18 June 2004, a solo hiker traveling off-trail was attacked after a surprise encounter with 2 grizzly bears that were digging biscuitroot (*Lomatium* spp.) tubers behind a hill in Hayden Valley. The peak period during which grizzly bears dig biscuit root is from mid-June through July (Mattson et al. 1991, Craighead et al. 1995). Had a seasonal closure been in effect in Hayden Valley during the period of greatest biscuit root consumption (15 Jun–31 Jul) from 1970 to 2017, it potentially would have prevented 4 of the 10 (40%) grizzly bear–inflicted human injuries that occurred in Hayden over the past 47 years.

***Closure for seasonal predation on ants***

Graham (1978) reported ants (Formicidae) in grizzly bear scats collected from Hayden and Pelican valleys. The peak period during which grizzly bears consume ants in the GYE is from late June through the end of July (Craighead et al. 1995). Had a seasonal closure been in effect in Hayden Valley from 1970 to 2017 during the peak period in which grizzlies consume ants (21 Jun–31 Jul), it potentially would have prevented only 3 of the 10 (30%) grizzly bear attacks that occurred in Hayden over the past 47 years. A closure of Hayden Valley during the peak period of ant consumption likely would not be very effective at reducing grizzly bear attacks in the valley.

***Closure for seasonal predation on pocket gopher neonates***

In addition to predation on adult pocket gophers and kleptoparasitism of their food caches, grizzly bears also exploit pocket gopher nests containing neonates. Exploitation of pocket gopher nests peaks during July after parturition (Mattson 2004b). Had a seasonal closure been in effect in Hayden Valley from 1970 to 2017 during the peak period in which grizzlies exploit pocket gopher nests (1 Jul–31 Jul), it potentially would have prevented only 3 of the 10 (30%) grizzly bear attacks that occurred in Hayden over the past 47 years. A closure of Hayden Valley during the peak period of pocket gopher nest exploitation likely would not be very effective at reducing grizzly bear attacks in the valley.

***Closure for seasonal grazing on elk thistles***

Elk thistle (*Cirsium foliosum*) is one of the most frequently occurring foods found in grizzly bear scats in Hayden Valley (Mealey 1975, Graham 1978). Peak consumption of elk thistle occurs during July after the stems have bolted (Mattson et al. 1991). Had a seasonal closure been in effect in Hayden Valley from 1970 to 2017 during the period of greatest elk thistle consumption (1 Jul–31 Jul), it potentially would have prevented 3 of the 10 (30%) grizzly bear–inflicted human injuries that occurred in Hayden Valley over the past 47 years.

***Closure for seasonal scavenging of rut-killed bison carcasses***

Some adult male bison are gored and die in Hayden Valley each year during the bison rut. The bison rut occurs from mid-July through mid-August (Meagher 1973), although some males do not die from goring-related injuries and infection until early to mid-September (R. Wallen, Bison Office, YNP, personal communication). These bison carcasses generally attract multiple grizzly bears for several days. As many as 23 grizzly bears have been observed congregating around a single bison carcass in Hayden Valley. Closing Hayden Valley during the period of rut-related bison mortality could reduce the chances of hikers encountering bears at bison carcasses. Had a seasonal closure been in effect in the Hayden Valley during the period of rut-related bison mortality (15 Jul through 15 Sep) from 1970 to 2017, it potentially would have prevented 6 of the 10 (60%) grizzly bear–inflicted human injuries that occurred in Hayden Valley over the past 47 years.

***Closure for seasonal grazing on strawberries***

Graham (1978) reported strawberry (*Fragaria virginiana*) in grizzly bear scats collected from Hayden and Pelican Valleys. The peak period during which grizzly bears consume strawberry in the valley–plateau regions of YNP is during August (Mealey 1975). Had a seasonal closure been in effect in Hayden Valley from 1970 to 2017 during the peak period in which grizzlies consume strawberry (1 Aug–31 Aug), it potentially would have prevented only 3 of the 10 (30%) grizzly bear attacks that occurred in Hayden over the past 47 years. A closure of Hayden Valley during the peak period in which grizzly bears graze strawberry likely would not be very effective at reducing grizzly bear attacks in the valley.

***Closure for seasonal grazing on buttercups***

Graham (1978) reported buttercup (*Ranunculus* spp.) in grizzly bear scats collected from Hayden and Pelican valleys. Based on scat analysis, the peak period during which grizzly bears graze buttercup in the valley–plateau regions of YNP is during August (Mealey 1975). Had a seasonal closure been in effect in Hayden Valley from 1970 to 2017 during the peak period in which grizzlies graze buttercup (1 Aug–31 Aug), it potentially would have prevented only 3 of the 10 (30%) grizzly bear attacks that occurred in Hayden over the past 47 years. A closure of Hayden Valley during the peak period in which grizzly bears graze buttercup likely would not be very effective at reducing grizzly bear attacks in the valley.

***Closure for seasonal grazing on whortleberries***

Graham (1978) reported whortleberry (*Vaccinium scoparium*) in grizzly bear scats collected from Hayden and Pelican Valleys. The peak period of whortleberry consumption in the GYE is during August (Mattson et al. 1991). Had a seasonal closure been in effect in Hayden Valley from 1970 to 2017 during the peak period in which grizzlies consume whortleberry (1 Aug–31 Aug), it potentially would have prevented only 3 of the 10 (30%) grizzly bear attacks that occurred in Hayden over the past 47 years. A closure of Hayden Valley during the peak period in which grizzly bears graze whortleberry likely would not be very effective at reducing grizzly bear attacks in the valley.

***Closure for seasonal grazing on clover***

Grizzly bears eat clover (*Trifolium* spp.) wherever it is common in their range (Mattson 1990). Pure, dense clover patches will sometimes attract and hold multiple bears in a relatively small area (Gunther 1991). There is increased risk of human–bear encounters in clover swards because of bear attraction to clover patches. In YNP, grizzly bears consume clover from May to September (Gunther 1991) with peak use in August and early September (Gunther 1991, Mattson et al. 1991). Had a seasonal closure been in effect in Hayden Valley from 1970 to 2017 during the peak season of clover consumption (1 Aug–7 Sep), it would have potentially prevented 4 of the 10 (40%) grizzly bear–inflicted human injuries that occurred in Hayden over the past 47 years.

***Closure for seasonal predation on rutting adult male elk***

Mealey (1975) observed evidence of grizzly bears preying on adult male breeding elk in Hayden Valley during the post-growing season when forbs had become desiccated. Breeding males are likely less vigilant of predators during the rut. Analysis of grizzly scats collected in the Valley–Plateau areas of YNP indicated the peak period of consumption of male elk was from 1 September to 15 October. Had a seasonal closure been in effect in Hayden Valley from 1970 to 2017 during the peak period in which grizzlies prey on male elk (1 Sep–15 Oct), it potentially would have prevented only 2 of the 10 (20%) grizzly bear attacks that occurred in Hayden over the past 47 years. A closure of Hayden Valley during the peak period of male elk predation likely would not be very effective at reducing grizzly bear attacks in the valley.

***Closure for seasonal digging of yampa roots***

Graham (1978) reported yampa roots (*Perideridia* spp.) in grizzly bear scats collected from Hayden and Pelican Valleys. In YNP, grizzly bears grub yampa roots from July through October, with peak use in September and October (Mattson et al. 1991). Had a seasonal closure been in effect in Hayden Valley from 1970 to 2017 during the peak period of yampa root consumption (1 Sep–31 Oct), it potentially would have prevented only 2 of the 10 (20%) grizzly bear attacks that occurred in Hayden over the past 47 years. A closure of Hayden Valley during the peak period in which bears dig yampa roots likely would not be very effective at reducing grizzly bear attacks in the valley.

***Closure for seasonal digging of False Solomon’s seal rhizomes***

Mealey (1975) observed feeding sign of a grizzly digging up the rhizomes of False Solomon’s seal (*Maianthemum* sp.) in Hayden Valley in early October. Analysis of grizzly scats collected in the Valley–Plateau areas of YNP indicated the peak period of consumption of *Maianthemum* sp. was from September through October (Mealey 1975). Had a seasonal closure been in effect in Hayden Valley from 1970 to 2017 during the peak period in which grizzlies consume *Maianthemum* sp. rhizomes (1 Sep–31 Oct), it potentially would have prevented only 2 of the 10 (20%) grizzly bear attacks that occurred in Hayden over the past 47 years. A closure of Hayden Valley during the peak period in which bears dig *Maianthemum* sp. rhizomes likely would not be very effective at reducing grizzly bear attacks in the valley.

***Closure for seasonal mushroom feeding***

Mealey (1975) reported finding feeding sign of a grizzly bear consuming the caps and stems of mushrooms (*Russula* sp.) in Hayden Valley in early October. Analysis of scats collected in the Valley–Plateau areas of YNP indicated grizzlies consume *Russula* sp. from August to October, with the peak period of consumption of mushrooms from September through October (Mealey 1975). Had a seasonal closure been in effect in Hayden Valley from 1970 to 2017 during the peak period in which grizzlies consume mushrooms (1 Sep–31 Oct), it potentially would have prevented only 2 of the 10 (20%) grizzly bear attacks that occurred in Hayden over the past 47 years. A closure of Hayden Valley during the peak period in which bears consume *Russula* sp. likely would not be very effective at reducing the frequency of grizzly bear attacks in the valley.

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