Bison and elk responses to winter recreation in Yellowstone National Park
by Amanda Ruth Hardy

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Fish and Wildlife Mangement
Montana State University

Abstract:
The National Park Service (NPS) is tasked with protecting wildlife and providing public access to parklands; winter recreation in Yellowstone National Park (YNP) has challenged NPS managers to balance this dual mandate. This study addresses bison and elk responses to winter recreation in the upper Madison River drainage of YNP. Using data on weather; winter recreation activity; elk and bison distribution, behavior, abundance, and fecal stress hormone (glucocorticoid) levels collected during the winters of 1998—1999 and 1999—2000, I developed models to analyze if variables related to winter recreation contributed to bison and elk distribution, behavior, and stress hormone levels responses. As distance between human activities and bison and elk decreased, behavioral responses increased. Both species behaviorally responded more often to people off-trail than to people on trails ($P < 0.001$ for both species), and these activities prompted more behavioral responses than activities on roads. Elk were farther from the road ($P = 0.092$) and had higher stress levels (unknown elk: $P = 0.051$; collared cow elk: -P=0.002) after-exposure to >7,500 cumulative vehicles entering the West Yellowstone gate. Elk residing along the road segment with the greatest amount of oversnow vehicle (OSV) activity had higher stress levels (unknown elk: $P < 0.001$; collared cow. elk: $P = 0.004$) and may have been displaced from habitat along the road (distance: P = <0.001; numbers sighted: $P = 0.082$) compared to elk residing along the less-traveled road segment. Collared cow elk stress levels increased ($P = 0.057$) while the probability of bison and elk behaviorally responding to human activities on the road decreased ($P = 0.001$ for both species) as daily vehicles entering the West Yellowstone gate increased. The predictability and frequency of OSV activities facilitated habituation to the majority of winter recreation activities. Abundance estimates indicated populations of wintering bison increased and wintering elk remained stable over 20 years. Despite varying responses to increased winter visitation since the late 1970s, bison and elk return to winter in the same area each year, coexisting with winter recreation without incurring losses at the population level.

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APPROVAL

of a thesis submitted by

Amanda Ruth Hardy

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

The National Park Service (NPS) is tasked with protecting wildlife and providing public access to parklands; winter recreation in Yellowstone National Park (YNP) has challenged NPS managers to balance this dual mandate. This study addresses bison and elk responses to winter recreation in the upper Madison River drainage of YNP. Using data on weather; winter recreation activity; elk and bison distribution, behavior, abundance, and fecal stress hormone (glucocorticoid) levels collected during the winters of 1998—1999 and 1999—2000, I developed models to analyze if variables related to winter recreation contributed to bison and elk distribution, behavior, and stress hormone levels responses. As distance between human activities and bison and elk decreased, behavioral responses increased. Both species behaviorally responded more often to people off-trail than to people on trails ($P < 0.001$ for both species), and these activities prompted more behavioral responses than activities on roads. Elk were farther from the road ($P = 0.092$) and had higher stress levels (unknown elk: $P = 0.051$; collared cow elk: $P = 0.002$) after exposure to >7,500 cumulative vehicles entering the West Yellowstone gate. Elk residing along the road segment with the greatest amount of oversnow vehicle (OSV) activity had higher stress levels (unknown elk: $P < 0.001$; collared cow elk: $P = 0.004$) and may have been displaced from habitat along the road (distance: $P = <0.001$; numbers sighted: $P = 0.082$) compared to elk residing along the less-traveled road segment. Collared cow elk stress levels increased ($P = 0.057$) while the probability of bison and elk behaviorally responding to human activities on the road decreased ($P = 0.001$ for both species) as daily vehicles entering the West Yellowstone gate increased. The predictability and frequency of OSV activities facilitated habituation to the majority of winter recreation activities. Abundance estimates indicated populations of wintering bison increased and wintering elk remained stable over 20 years. Despite varying responses to increased winter visitation since the late 1970s, bison and elk return to winter in the same area each year, coexisting with winter recreation without incurring losses at the population level.

INTRODUCTION

Understanding and managing recreational impacts on wildlife is becoming more important as participation in outdoor activities increases and covers larger areas of land, and isolation of wildlife from humans decreases (Flather and Cordell 1995). Management policies for protected areas must balance a trade-off between public access and the impacts of human activities on animal populations. When human activities occur near wildlife, animals may show any of 4 basic responses: attraction, avoidance, habituation (Knight and Cole 1991), or no reaction. If human activity offers a reward, such as food, wildlife may be attracted to the activity. If the activity is unpredictable, rare, sporadic, or results in a negative outcome, such as harassment or injury, wildlife tend to avoid such stimuli (Aune 1981, MacArthur et al. 1982). Wildlife may habituate to stimuli, resulting in the decrease or disappearance of behavioral and/or physiological responses (Eibl-Eibesfeldt 1970), especially if the activity is predictable and frequent with no positive or negative consequences. Animals may never show any level of response to stimuli. But even when an animal lacks an observable behavioral response, a non-observable physiological stress-response may occur (MacArthur et al. 1982). A stress response may occur when an animal perceives something as a threat, triggering a cascade of hormone secretions that eventually releases adrenaline and glucocorticoids (GCs) from the adrenal gland. The short, quick release of adrenaline prepares the body for the immediate "fight or flight" response. This is followed by the slower, extended release of GCs from the adrenal cortex (MacArthur et al. 1982, Sapolsky 1992), which reassigns the body's resources to back up the "fight or flight" response hours after the initial cognition of the threat. If this stress-response is repeated, sustained or prolonged, it can cause fatigue, hypertension, gastric ulcers, impaired disease resistance, less efficient metabolism, impaired growth, suppressed reproduction, and accelerated neural degeneration during aging (Mayes 1979, Sapolsky 1992).

Recreational activity combined with environmental factors such as deep snow, cold temperatures and reduced food availability may stress animal populations, which may result in illness or lower rates of reproduction and survival (Anderson 1995). Energy conservation during winter months is important to ungulate survival (Gates and Hudson 1979). Winter recreation activities such as snowmobiling and cross-country skiing occurring near wintering wildlife may impose disturbances of greater biological significance than other forms of recreation that occur during less energetically demanding times of the year.

In Yellowstone National Park (YNP), winter recreation is concentrated along valley bottoms where wildlife aggregate. Elk and bison winter in the valley bottoms due to reduced snow depths associated with lower elevations and the geothermal activity in these areas. In the early part of the century few people ventured into YNP during the winter, but elk and bison have been exposed to increasing levels of winter recreation since 1955, when the first snowcoach trips to Old Faithful occurred, and 1964, when the first snowmobile travelers explored the park (Meagher 1993). Since then, winter visitation has become quite popular. In the early 1970s, YNP managers began grooming the snow on roads to accommodate more snow vehicles and allowed concessioners to operate overnight facilities for visitors and to restrict the use of oversnow vehicles (OSVs) to the road system. By the late 1970s, park-wide annual winter visitation was approximately 48,000 people, prompting the first intensive investigation of the impacts of winter recreationists on wildlife in the upper Madison River drainage of YNP by Aune (1981). He documented instances of people approaching wildlife and inhibiting wildlife movements and found that wildlife was displaced from habitat near roads and trails. These observations were relatively infrequent, however, and he observed that within the first two weeks of the winter season, animals habituated to the presence of humans, vehicles, and noise along groomed roads, and concluded that winter recreation was not a major factor influencing wildlife movement, distribution, or survival.

Since Aune's (1981) study, winter visitation has steadily increased. Between the winters of 1993—1994 and 1997—1998, the total annual number of snowmobile and snowcoach passengers and skiers coming to YNP averaged 90,748 (National Park Service 1999). Concerned with the effects of increased winter visitation, advocacy groups filed a suit against the National Park Service (NPS) in 1997. In response, the NPS agreed to prepare an environmental impact statement (EIS) addressing winter use management in YNP, Grand Teton National Park (GTNP), and the John D. Rockefeller, Jr., Parkway. Beyond the scope of the YNP/GTNP winter use management EIS, the US Department of the Interior banned snowmobiles from most National Parks in 2000, which has been met with litigation from the snowmobile industry and snowmobile enthusiast groups.

This paper addresses winter recreation activity influences on elk and bison abundance, distribution, behavior, and stress hormone levels in the upper Madison River drainage of YNP. I focused on bison and elk due to their abundance and proximity to human activity in the study area. I evaluated how OSV activity, the most common winter recreation activity, and activities afoot, such as trail and off-trail skiing and snowshoeing, affected bison and elk in the study area. As a follow up to Aune's (1981) conclusion that bison and elk habituated to winter recreation activities, I hypothesize that elk and bison avoid winter recreational activities but that these responses decrease as the animals habituate to the frequent and predictable patterns of winter recreation in the study area. I also hypothesize that while elk and bison may observably habituate behaviorally, their physiological stress levels will increase as daily and cumulative winter recreation levels increase.

I documented human activity levels, human-ungulate interactions, elk and bison distribution patterns in relation to the road corridor and areas of human activity, and measured elk and bison fecal glucocorticoid (FGC) levels as a physiological index of stress. With these data, I used regression models to test if the human activity in the study area affected elk and bison. I specifically tested if daily and cumulative numbers of vehicles entering the study area or types of winter recreation activities and human behaviors contributed significantly to elk and bison distribution, behavior, and stress hormone responses after controlling for environmental and herd characteristics that contribute to these responses. In addition to these quantitative analyses, to the extent possible, I compare current elk and bison behaviors and abundances to Aune's (1981) baseline study to evaluate potential differences to 20 years ago, when winter visitation was less than it is currently.

STUDY AREA

The study area was defined as the winter ranges for elk and bison within the Madison, Firehole and Gibbon drainages, referred to as the upper Madison River drainage. This area encompassed approximately 27,000 ha (Ferrari 1999) extending from Norris Geyser Basin south to Old Faithful and along the Madison River to the western boundary of the park at West Yellowstone, Montana (Figure 1). Physiography was dominated by river valleys and canyons that cut through the rhyolitic plateau (Despain 1990) with elevations that ranged from 2250–2800 meters. Extensive flat meadows lined the valley bottoms of the major drainages. The geyser basins at Norris and along the Firehole River, along with many other smaller geothermally-influenced areas, produced warm ice-free rivers, creeks and pockets where the severity of winter was reduced, allowing photosynthesizing plant communities to grow throughout the winter (Meagher 1973, Despain 1990). Lodgepole pine (*Pinus contorta*) dominated forested areas with occasional stands of Douglas fir (*Pseudotsuga mensiesii*) and spruce/fir (*Picea engelmanni/Abies lasiocarpa*) interspersed. Wet meadows were characterized by sedges (*Carex* spp.) and marsh reedgrass (*Calamagrostis* spp.) while dry meadows were characterized by sagebrush (*Artemisia* spp.) and grasses (*Festuca idahoensis*, *Poa* spp.) (Craighead et al. 1973, Aune 1981).

Winters were long and cold and summers were short and cool. Snow depths typically exceeded 91 cm in nonthermal areas (Eberhardt et al. 1998). The valley bottom snowpack began to melt in early March while the higher elevation plateau snowpack

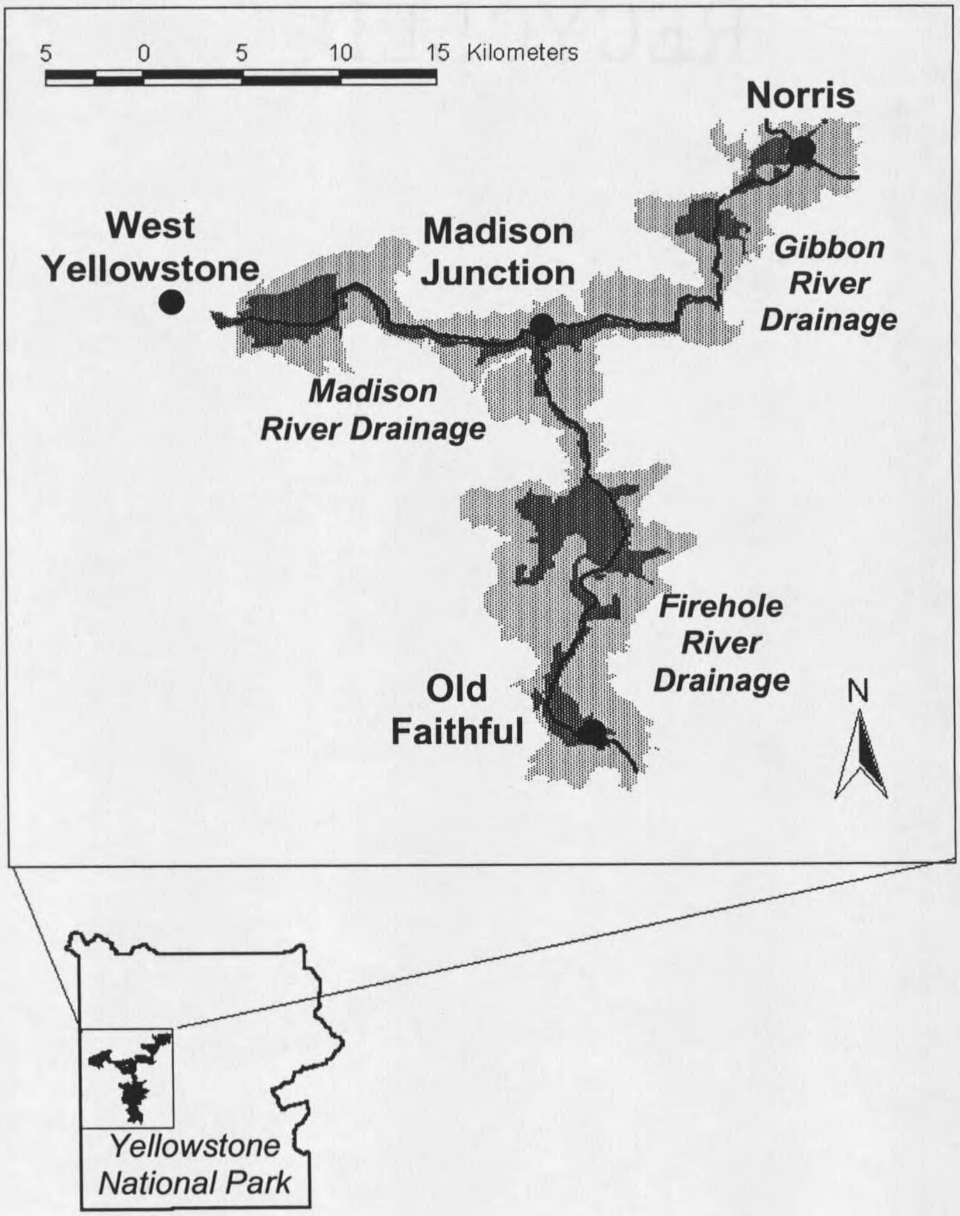

Figure 1. The upper Madison River drainage study area of Yellowstone National Park. The lighter shaded area represents the elk winter range while the darker shaded bison winter range is constricted to the valley bottoms overlapping the elk range (Ferrari 1999). Roads, indicated in black, follow the valley bottoms.

around the perimeter of study area did not start to melt until mid-April or May (Ferrari 1999). Mean annual temperature at the western boundary of the study area is 1.7 C°, with 15.3 C° in the warmest month of July and –10.6 C° in the coldest month of January (National Oceanic and Atmosphere Administration records, as cited in Aune 1981).

Bison and elk were the most abundant large animals encountered in the study area. The elk population was primarily non-migratory, remaining within the borders of the park throughout the year (Craighead et al. 1973) and was not exposed to human hunting pressure. The study area provided primarily winter range for the central Yellowstone bison herd that numbered approximately 1,600 to 2,200 (Bjornlie and Garrott 2001, S. C. Hess unpublished data). Predators in the area included wolves (*Canis lupus*), coyotes (*Canis latrans*), and, during the non-hibernation periods, black bears (*Ursus americanus*), and grizzly bears (*Ursus arctos*). Trumpeter swans (Olor buccinator) and bald eagles (Haliaeetus leucocephalus) also occurred in the area.

Human activity in the upper Madison River drainage occurred in a predictable pattern. Vehicular travel within the study area was restricted to paved, 2-lane roads, including 22 km from the West Entrance Station to Madison Junction, 22 km from Madison Junction north to Norris Junction, and 26 km from Madison Junction south to Old Faithful. On November 1, these roads were closed to the public, and wheeled vehicle (WV) traffic was limited to YNP personnel. Once a base of snow accumulated, human travel on the roads transitioned from WVs to snowmobiles and snowcoaches, together referred to as over-snow vehicles (OSVs) and by mid-December the park opened to the public for the winter season. In mid-March the park was closed to the public, the roads were plowed and for approximately 6 weeks WV traffic was limited to YNP personnel only. Public, non-motorized recreation was allowed for 3 weeks before the roads were opened to public WVs for the summer season in the last week of April.

Roads within the study area accommodated the most winter recreational use in the park. Of all OSVs that entered YNP, 62% arrived at the West Entrance Station (NPS 1999), 69% traveled between Madison and Old Faithful, and 36% traveled between Madison and Norris (Friemund et al. 1999). In addition to OSV road traffic, cross-country skiers, snowshoers, and other foot traffic occasionally ventured off-trail but more typically used the 80 km of available trails, mostly in the Old Faithful and Norris areas and at the geyser basin areas along the Firehole River.

METHODS

I collected data on weather; daily winter recreation activity; elk and bison distribution, behavior and abundance; and collected elk and bison fecal samples from late November to mid-May of 1998—1999 and 1999—2000.

Weather

I gathered weather data to assess winter severity effects on elk and bison behavior, distributions and FGC levels. I obtained daily snow water equivalent (SWE) measurements, an index of the mass of water contained in a column of snow, from the Natural Resources Conservation Service (NRCS) automated SNOTEL site in West Yellowstone, Montana (2,042 m) (http://www.wcc.nrcs.usda.gov/snotel/snotel.pl?sitenum=924&state=mt). I calculated average daily temperature using daily minimum and maximum air temperatures recorded at NPS weather stations located in the valleys at West Yellowstone, Madison Junction (2091 m), and Old Faithful (2264 m). I compared our SWE data to the winters Aune (1981) conducted his study and included SWE and average daily temperature as independent variables in our analyses.

Winter Recreation

I obtained the daily number of vehicles entering the NPS West Entrance Station at West Yellowstone, Montana, throughout the public OSV season and after the park opened to visitor WVs in the spring. When the park was closed to the public, I did not quantify YNP personnel vehicles traveling through the study area and considered this activity to be the "baseline" level of human activity. When the park was opened to public visitation, the number of vehicles entering the West Yellowstone gate was additive to the baseline level of human activity. I compared our OSV visitation data to Aune's (1981). In our analyses, I included total daily vehicles entering the West Entrance gate as an independent variable. Additionally, I defined a categorical "exposure" variable, with "low" for days that the park was closed and until 7,500 cumulative vehicles entered the West Entrance gate and "high" for each day after >7,500 cumulative vehicles entered the West Entrance gate. I included this exposure variable in our analyses to test if behavior, distribution or stress hormone responses habituated to human activity after a period of initial exposure.

Elk and Bison Abundance

I estimated the elk population in the study area at the onset of each winter field season by combining replicate Lincoln-Petersen population estimates from the previous spring and replicate composition surveys conducted during the fall rut. Radio collars (36–38) were maintained on cow and calf elk on the study area during the 2 years of the study. I traveled the road system and counted all collared and uncollared elk using binoculars and a spotting scope in early morning and late evening, when elk were most visible. A continuity-corrected Lincoln-Petersen population estimate was calculated for individual surveys (Seber 1982) conducted on 10 consecutive days in April when elk were aggregated in lower elevation meadows and after most winter mortality had occurred. The mean of the spring surveys was considered the estimate of the number of adult elk in the population entering the next winter (Rice and Harder 1977). Seven years of pre-wolf elk telemetry data showed no significant adult mortality from spring to the fall rut surveys (R.A. Garrott, unpublished data), and wolves were absent from the study system during the snowless seasons (Jaffe 2001). Fall rut replicate composition surveys were conducted on 11–12 consecutive days in late September-early October in the same manner as the spring surveys to determine the sex and age composition and estimate recruitment to the population. The proportion of cows and bulls in the adult population and the calf–cow ratio were calculated from these fall surveys. I multiplied the fall proportions of bulls, cows and calves each by the previous spring population estimate, and added these together to yield a total population estimate at the onset of winter.

I conducted censuses of the bison within the study area every 10 days during 1998—1999 and every 14 days during 1999—2000. Using intensive ground surveys techniques (Ferrari 1999, Bjornlie and Garrott 2001), the study area was divided into 72 units with 6 travel routes delineated that completely traversed all the units. Surveys lasted 2 days and consisted of 3 people separately traversing 1 route each day, locating all bison within each unit. I surveyed the Gibbon and Madison drainages 1 day and the Firehole drainage on the other day to minimize the possibility of bison moving from 1 area to another between survey days. For each group of bison observed, I recorded the date and time, location of the group recorded on USGS 7.5 minute maps in Universal Transverse Mercator (UTM) coordinates, and classified the age/sex group composition as described for the radiocollared elk locations. I compared our bison abundance estimates to Aune's (1981) bison population estimates.

Elk and Bison Behavior and Distribution

I conducted surveys from roads, trails, and in areas off–trails to collect data on elk and bison distribution in relation to roads and trails, winter recreation activities and wildlife responses. I sampled for these data on each of the 3 road segments in the study area twice a week, for a total of 6 independent surveys conducted at different times to capture daily and weekly variation in wildlife and human activities. Surveys on the road were conducted along the 3 road segments in the study area (Fig. 1) while snowmobiling or driving ≤ 50 km/hr. Trail surveys were conducted from established trails and boardwalks in the Upper Geyser Basin near Old Faithful and the Norris Geyser Basin. I conducted off–trail surveys in areas remote from roads and established trails. I surveyed approximately 10 km of trails and 10 km off–trails every 2 weeks.

For all surveys, I recorded the route surveyed and all elk and bison groups observed. For each group, I recorded distance from road, trail or observer; species; and group size. I used a laser range finder to determine perpendicular distance from road, trail, or observer. In situations beyond the capabilities of the range finder (>500 m), I estimated this distance. During road surveys, I categorized if people, including the observer, 1) stopped their vehicle; 2) stepped out on foot; or 3) ventured off the road or trail. During trail and off-trail surveys I coded if people were 1) on the trail or 2) off-trail. I used the highest human activity coded for each observation in our analysis, with the higher coded categories representing less predictable activities. I recorded elk and bison response behaviors for the majority of the group. Response behaviors were categorized as no apparent response, look/resume, ambled away, attention/alarm, and flight (Chester 1976). I plotted proportions of the 5 behavioral responses during 6 consecutive 21-day periods when bison and elk were exposed to OSVs. Observations from 1999—2000 were only represented in periods 2–5. Period 1 encompassed 6 days in December 1998 when the park was not open to the public but administrative traffic had changed to OSVs and period 6 included 7 days at the end of the normal public OSV season in March 1999 (the 1999—2000 OSV season ended in period 5 due to lack of snow). For logistic regression analyses, I created a binary behavioral response variable by coding no apparent response as 0 and pooling look/resume, attention/alarm, amble away, and flight responses together and coding these responses as 1.

<u>Fecal Glucocorticoid Sampling</u>

I collected feces from radiocollared cow elk, unknown elk and bison to measure FGC levels. To obtain spatially and temporally balanced sampling of unknown elk and bison feces, I divided the study area into 5 sampling areas: West Yellowstone to Madison Junction; Madison Junction to approximately 11 km north of Madison Junction; approximately 11 km north of Madison Junction to Norris; Madison Junction to approximately 13 km south of Madison Junction; and approximately 13 km south of Madison Junction to Old Faithful. I attempted to collect 10 fecal samples from both elk and bison per sampling area in 2 week intervals. I attempted to collect fecal samples that were <2 days old, using recent snowfall, tracks, and knowledge of groups recently occupying an area to aid in our judgment of fecal sample age.

I collected fecal samples from a total of 45 radiocollared cow elk. Age of collared elk, which was included as a variable in our analyses, was determined based on cementum annuli of an upper canine tooth (Hamlin et al. 2000) extracted at the time the animal was collared. I determined the order and frequency of locating the radiocollared cow elk using a restricted randomization design (Garrott et al. 1996). With the study area divided into 6 regions, 2 field team members were randomly assigned 1 region each morning and afternoon. Radiocollared elk in those areas were then located in a randomly determined order using radio-telemetry. Animals within each region were resampled only after animals in all 6 regions were located. For each collared elk observed, I recorded date, time, and UTM location. I recorded age/sex categories of all elk associated with the marked individual (adult cows, adult bulls, and calves). When I witnessed a defecation event, after all data were recorded and the elk had moved away from the area, I collected a fecal sample from the collared cow and from other elk in the group. Upon collection, I recorded date, time of collection, species, and the identity of the animal. Fecal samples were collected in 50 mL tubes, stored at –20°C in the field and at –80°C in the laboratory until the assays were performed.

Fecal Sample Extraction and Validation of Radioimmunoassay

Fecal samples were dried using a rotary evaporator, pulverized, and 0.1-0.2 g of the resulting powder was boiled in 10 ml of 100% ethanol for 20 minutes. After centrifuging (15 minutes at 500 g), supernatant was recovered, dried and reconstituted in 1 ml methanol. This extract was vortexed for 1 minute, placed in an ultrasonic glass cleaner for 30 seconds to free adhering particles, then vortexed for 15 seconds. Extracts were stored at –80 C°.

I validated a double-antibody [125I] corticosterone radioimmunoassay (RIA; ICN Biomedicals, Costa Mesa, California, 92626 USA) for both elk and bison fecal extracts (Cekan 1975; Millspaugh 1999). This antiserum cross-reacts little with steroids other than corticosterone (deoxycorticosterone 0.34%; testosterone 0.10%; cortisol 0.05%; progesterone 0.02%; < 0.01% for all other steroids tested), the specific FGC hormone I quantified in our samples. I assayed all extracts in duplicate at dilutions of 1:50 (100 μl) for elk and 1:4 (100 μl) for bison. Serial dilutions of pooled elk fecal extracts (range =1:4 to 1:128) and pooled bison fecal extracts (range=1:4 to 1:64) yielded antibody–binding curves parallel to the standard curve (range = 25–1000 ng corticosterone/mL). Mean recovery of known amounts of corticosterone added to elk (range = 25–250 ng corticosterone/mL) and bison (range = 25-1000 ng corticosterone/mL) fecal extract was 89 ± 1.6% ($y = 4.29 + 0.89x$, $R^2 = 0.99$) and 110 ± 2.9% ($y = 17.59 + 1.10x$, $R^2 = 0.99$), respectively. Elk extract inter-assay coefficient of variation (CV) was 6.9% for a low internal control (*n* = 39, 51–68% binding) and 8.3% for a high internal control (*n* = 39, 22–34% binding) while bison extract inter-assay CV was 8.1% for a low internal control (*n* = 21, 51–67% binding) and 8.3% for a high internal control (*n* = 21, 15–29% binding). Mean intra–assay CV was 2.1% and 2.6% for elk and bison extracts, respectively. The assay sensitivity 95% confidence interval was 14.6–17.1 ng/ml (20–24% binding) for elk extracts and 10.3–16.4 ng/ml (14–23% binding) for bison extracts. Elk and bison FGC levels were expressed as ng of corticosterone hormone excreted per gram of dry feces.

Determination of Lag-time to Detectable FGC Response

In order to appropriately attribute time-dependent covariates (SWE, average daily temperature, daily and cumulative daily visitation levels) for the bison and elk FGC data analyses, we needed an estimate of the approximate lag-time from a stressful event to corresponding secretion of GCs in feces. We used the results of an adrenocorticotropin (ACTH) challenge for elk conducted by Millspaugh (1999), and conducted an ACTH challenge for bison. I isolated 2 yearling bison cows from a captive herd and collected their feces 20 hours prior and just before injecting 1 of the cows with ACTH (5–10 g Acthar gel/100 kg body mass, IM). The other bison served as a control animal. I collected samples of fecal deposits from the pen approximately every 6 hours for 49 hours post–injection. Fecal samples were collected, stored, and assayed as described above.

The captive bison injected with ACTH experienced an increase in FGC levels (Figure 2). FGC levels from fecal samples collected 20 hours prior to the injection and just prior to injection measured 343 and 207 ng/g dry feces for the treated and control bison, respectively. Peak FGC levels in samples collected 17 and 25 hours post-injection from the treated bison were observed at 742 and 740 ng/g dry feces, respectively. FGC levels dropped back down to 348 ng/g dry feces 49 hours post-injection. Using the same RIA and ACTH challenge methods, Millspaugh (1999) found the peak in cow elk FGC levels approximately 23 hours post-injection. Using this information, I attributed time-dependent variables (SWE, average daily temperature, daily and cumulative vehicle

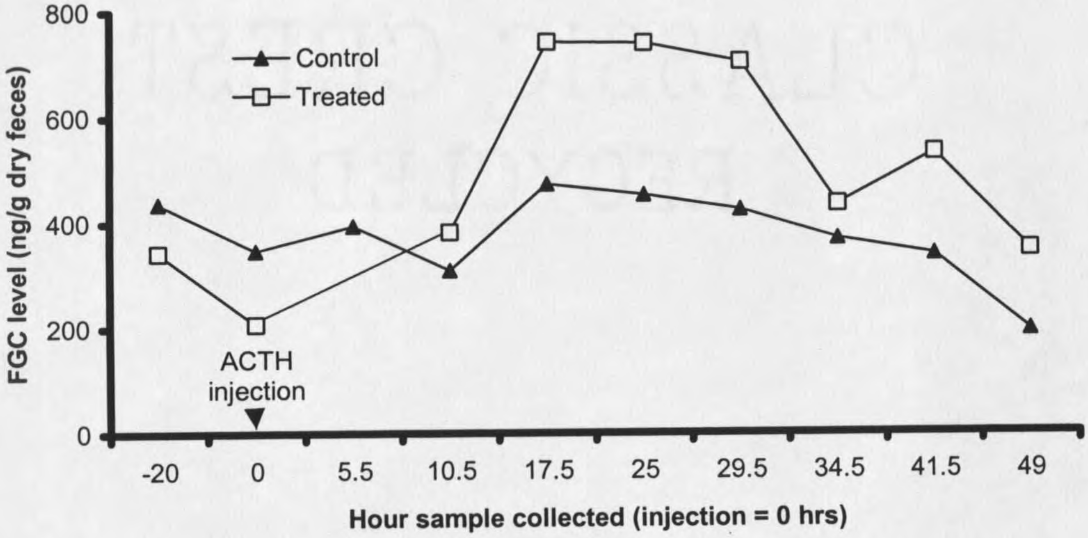

Figure 2. Fecal glucocorticoid (FGC) levels measured for an experimentally ACTH-injected cow bison and a control cow bison. The peak level of FGC secretion for the experimental bison occurred approximately 17 to 25 hours post-injection.

entering the West Yellowstone gate) from 24 hours prior to the date the fecal sample was collected when constructing the FGC models.

Analytical Methods

To test hypotheses about how winter recreation might contribute to elk and bison distribution, behavior, and stress hormone responses, I developed a priori models with variables relevant to human activities and controlled for environmental conditions and biological characteristics of elk and bison that may naturally contribute to the responses of interest. I controlled for year, cumulative season days (day 1 = Dec 1), SWE, average daily temperature, meters from road or distance from human activity, and number of animals in group. I then incorporated variables of interest representing levels and types of human activities, including road segment (West Yellowstone to Old Faithful vs.

Madison Junction to Norris), vehicle type (WV vs. OSV), number of daily vehicles entering the West Entrance gate, exposure (<7500 cumulative vehicles vs. >7500 cumulative vehicles), and human activity occurring during observations.

I developed 7 multiple linear regression models to test if human activity was related to elk and bison distribution and FGC levels. I modeled distances of elk/bison groups sighted from the road, total numbers of elk/bison sighted during road surveys, and FGC levels in unknown elk, unknown bison, and radiocollared cow elk. I log10 transformed the response variables to achieve normality. For the distance model response variable, I changed all observations of elk and bison that were on the road from 0 to 1 meter to allow for log10 transformation. For the statistically significant variables ($P \leq 0.10$) that contributed to the response in each full model, I reported partial regression results and included least means squared values for the statistically significant anthropogenic categorical variables for future comparisons.

I used logistic regression fit by maximum likelihood to test if human activity contributed to 4 models of elk and bison behavioral responses from the pooled trail/off-trail and road survey data. I started with a full model with all applicable variables. A reduced model was then run with variables achieving significant ($P \leq 0.10$) z-values from the full model. I then reassessed the importance of the variables dropped from the full model by comparing the likelihood values of the full model and reduced model, which yielded a deviance value. Small p-values ($P \leq 0.10$) from the deviance revealed that at least one of the dropped variables contributed to the response (Collett 1991). None of the deviances indicated that the dropped variables were significant contributors to the full model and our reduced models were the final models reported. I used Minitab (Release 13) for data analyses.

RESULTS

Weather

The snowpack began to accumulate in November, peaked in April, and melted off in May though differences between the two years of our study were evident. The 1998—1999 accumulation peaked at 29 cm, 20% greater than the 33 year average peak SWE (23.1 cm) for the same location, while 1999—2000 peaked at 17.5 cm, 25% lower than the 33 year average. Peak SWE during Aune's (1981) 2 year study was 27.2 cm and 23.1 cm. Average daily temperatures ranged from –31°C to 7°C with a mean of –7 C° (SE = 0.50) in 1998—1999 and from –21°C to 7°C, averaging –5°C (SE = 0.46) in 1999—2000.

Winter Recreation

The public OSV season was 89 days from 16 December 1998 through 14 March 1999, and 82 days from 15 December 1999 through 6 March 2000 (Figure 3). Cumulative totals of 45,785 and 40,298 OSVs entered the West Entrance gate in the 1998—1999 and 1999—2000 winter seasons. Daily numbers of OSVs entering the West Entrance gate in 1998—1999 averaged 514 (SD = 208) and peaked at 1168 OSVs on 28 December while in 1999—2000, an average of 486 (SD = 222) OSVs entered the West Entrance gate daily and peaked at 1010 on 19 February. Peak visitation typically occurred on weekends and holidays while fewer vehicles entered the park on work days. For both years of this study, the threshold of 7500 vehicles changed from "low" to "high" on December 31, and was reset to "low" the day after the OSV season closed. In the