The National Park Service

WILDLIFE RESPONSES TO WINTER RECREATION IN YELLOWSTONE NATIONAL PARK

2004 ANNUAL REPORT
(December 12, 2003 through April 1, 2004)

Collaborative Effort by the:

Yellowstone Center for Resources
Resource Management & Visitor Protection
&
Montana State University

Report prepared by:

P.J. White and Troy Davis
Yellowstone Center for Resources
&
Dr. John Borkowski
Montana State University

in collaboration with

Dan Reinhart, Craig McClure, Patrick Perotti
Resource Management & Visitor Protection

July 14, 2004

Executive Summary

Staff from the Yellowstone Center for Resources and Resource Management & Visitor Protection Office monitored the behavioral responses of wildlife to motorized winter recreation during December 12, 2003 through April 1, 2004, for comparison to data from previous and future winters. We used snowmobiles and wheeled vehicles to conduct repeated surveys of wildlife responses to motorized winter use vehicles and human activities along nine groomed or plowed road segments. Our sampling unit was the interaction between motorized winter use and an observed group of wildlife within 500 meters of the road. We focused our monitoring on the responses of bison, elk, and trumpeter swans to motorized winter use vehicles owing to the proximity and/or perceived sensitivity of these species to motorized vehicles during winter.

Snow pack during early winter (i.e., October and November of 2003) was less than the historic average since 1981. Snow pack was approximately average by late winter, however, with the exception of the northern range area where snow pack remained below average throughout the winter. There was relatively low motorized use by visitors during winter 2004, compared to previous winters. Approximately 16,000 "over-the-snow" vehicles (i.e., snowmobiles and snow coaches; OSVs) entered the park's west entrance during winter 2004, compared to >22,000 OSVs during winter 2003 (which was also a relatively low visitation winter owing to poor snow pack). This lower visitation resulted, in part, from court orders in December and February and the accompanying uncertainty imposed on motorized recreation in the park.

Similar to previous winters since 1999, the responses of most wildlife species to OSVs and associated humans during winter 2004 were typically minor, with 58% (n = 1,296) of the 2,239 total observed wildlife responses categorized as no apparent response, 18% (n = 410) look/resume, 11% (n = 252) attention/alarm, 9% (n = 196) travel, 4% (n = 82) flight, and <1% (n = 3) defense. Wildlife responses to motorized winter use were consistent across species (bison, elk, swans), but the magnitude of the responses varied considerably among species. The likelihood of observing an active response to snow coaches or increasing numbers of snowmobiles in a group was similar for bison and swans, but significantly higher for elk. The likelihood of a response by each species decreased as distance from the road increased. The estimated odds of observing an active response compared to no response by bison or elk were significantly higher for administrative traffic than for guided OSVs. Also, wheeled vehicles elicited substantially fewer active responses by bison or elk than either administrative or guided groups of OSVs.

Independent studies of the responses of wildlife to OSVs and associated humans in Yellowstone National Park (Hardy 2001, Jaffe et al. 2002, Davis et al. 2004) during 1999-2004 have consistently reported that behavioral responses were relatively infrequent, short in duration, and of low intensity. Also, bison and elk were less likely to respond on days with higher traffic, likely due to some sort of habituation to the relatively continuous traffic. Gross estimates of the additional energy costs of travel or flight responses provoked by OSVs were relatively moderate for elk. Thus, animals exposed to OSVs likely do not incur a substantial energetic cost from such interactions, and these costs are likely easily compensated for without any significant demographic consequences. These findings are supported by trends in the abundance of bison and elk populations since the onset of motorized winter use in Yellowstone National Park, which

provide no evidence of population-level effects to ungulates from motorized winter use because their abundances either increased or remained relatively stable prior to wolf restoration. Thus, any adverse effects of motorized winter use to ungulates have apparently been compensated for at the population level.

Bison were observed on groomed roads during 311 of 2,597 observations of bison groups from December 12, 2003, through April 1, 2004. Thus, the vast majority of observed bison groups were using areas off the groomed roads, as has also been noted in previous winters. We are currently collaborating with researchers from Montana State University (Robert Garrott and John Borkowski) and California State University-Monterey Bay (Fred Watson and Susan Alexander) to analyze bison distribution and use of groomed roads during 1997-2004. We have also developed conceptual models of bison movement through the park based on remotely sensed landscape features (e.g., vegetation, terrain, and geothermal maps), snow pack measurements and modeling, and bison distribution data. These models have been used to predict bison trail systems and movements based on environmental constraints, which we intend to compare with the existing groomed road system to evaluate how grooming has affected bison movements. Draft reports of these analyses should be available in autumn 2004 or winter 2005.

Monitoring results during the winters of 2003 and 2004 suggest that several aspects of human behavior associated with motorized winter use could be modified through adaptive management to lessen the frequency of possible disturbances to wildlife. We recommend that training for guides, park staff, and concessionaires include the following voluntary recommendations: 1) stop at distances >100 meters from groups of wildlife, when possible; 2) reduce the frequency of multiple groups of motorized vehicles stopping in the same area to observe wildlife (i.e., reduce group size of motorized vehicles); 3) reduce the number of stops to observe wildlife and human activities away from vehicles during these stops; and 4) reduce interaction time because the likelihood of an active response by wildlife increases with longer interaction times. This training is essential because recreationalists often perceive that it is acceptable to approach wildlife more closely than empirical data indicates wildlife will tolerate (Taylor and Knight 2003). Because bison and elk behaviorally respond to people deviating from known, predictable routes, management measures that encourage visitors to stay on roads and established trails should also reduce wildlife disturbance rates.

It is unlikely that significant changes in behavioral responses or population-level effects in response to OSVs will be detected in the near future owing to the dominating effects of winter severity, predator off-take (including restored wolves), and human removals on the behavior and demographics of these populations. Thus, we recommend some substantive changes in the focus of winter use monitoring for wildlife during winter 2005. First, we recommend focusing the behavioral sampling of wildlife responses to OSVs in the Madison-Firehole drainages, while ceasing such monitoring throughout the remainder of the park. This approach will enable us to maintain continuity in behavioral sampling in the area of most intensive OSV use, while providing us to with more logistical flexibility to begin focusing other issues of importance. Second, we recommend using field crews to sample and map bison travel vectors (i.e., trail systems) in the west-central portion of the park. These data can be used to validate the predictions of conceptual models of bison movement through the park based on remotely sensed landscape features (e.g., vegetation, terrain, and geothermal maps), snow pack measurements and modeling, and bison distribution data. If the models predict bison trail systems and movements accurately, then we can compare model predictions of bison movement based on based on environmental constraints with the existing groomed road system to evaluate how grooming has affected bison movements. Third, we recommend the collection of snow-urine samples from northern and central Yellowstone ungulates to assess nutrition using the methodology described by Pils (1997). This information will enable us to better assess energetic costs and physiological consequences of various environmental conditions, interactions with OSVs, and road grooming.

In collaboration with professors from Montana State University, we are currently analyzing the combined data set collected by various researchers during 1999-2004 regarding wildlife responses to motorized winter use in Yellowstone National Park. The objectives of these analyses are to evaluate potential indicator variables of wildlife responses to human winter use, identify key conditions leading to responses, quantify variations in the frequencies of responses, and estimate thresholds for the most important disturbance factors. When data is pooled from multiple winter seasons, we will: 1) improve the likelihood of detecting any potential effects that truly exist, but currently cannot be detected from a single season's data; 2) strengthen the evidence for those effects already statistically significant; and 3) eliminate any spurious effects that may be marginally significant in any particular winter. Thus, we expect to have a more thorough and rigorous analysis of the behavioral responses of wildlife to OSVs completed by winter 2005.

TABLE OF CONTENTS

TABLES, FIGURES, AND APPENDICES

I. INTRODUCTION

On March 25, 2003, the National Park Service issued a Record of Decision (ROD; National Park Service 2003*a*) regarding the *Winter Use Plans – Supplemental Environmental Impact Statement for Yellowstone and Grand Teton National Parks and the John D. Rockefeller Jr., Memorial Parkway* (Winter Use SEIS; National Park Service 2003*b*). This decision encouraged the use of snow coaches for travel on groomed roads in Yellowstone National Park (YNP), but allowed the continued recreational use of snowmobiles on a limited basis. Recreational snowmobiles would be required to be Best Available Technology to mitigate effects to air quality and the natural soundscape. The ROD also restricted some groomed roads to snow coach-only motorized travel, and enacted use limits for "over-the-snow" vehicles (i.e., snowmobiles and snow coaches; OSVs) to regulate fluctuations in visitation and lessen their potential adverse effects. In addition, the ROD required that a trained guide accompany all snowmobiles operated in Yellowstone National Park beginning during winter 2005[1]. A commercial guide must accompany 80% of daily snowmobile entries during winter 2004. Monitoring and adaptive management were incorporated into the ROD to evaluate and address the long-term effects of management actions on park resources and values.

In preparation for these management changes, staff from the Yellowstone Center for Resources and Resource Management & Visitor Protection Office collaborated to monitor wildlife responses to winter recreation during winter 2003. The purpose of this monitoring effort was to collect baseline information on existing conditions for comparison to subsequent data collected after the implementation of changes in winter use management described in the ROD and SEIS. Such comparisons will enable us to evaluate the effectiveness of changes in winter use management at attaining desired conditions regarding wildlife. A report summarizing the results of efforts to monitor wildlife responses to winter recreation during winter 2003 was issued on January 21, 2004 (Davis et al. 2004).

During winter 2004, we planned to continue collecting baseline information on existing conditions for comparison to data from previous winters, as well as subsequent data collected after the implementation of changes in winter use management described in the ROD and SEIS. On December 16, 2003, however, Judge Sullivan of the Washington, D.C. District Court set aside the Winter Use SEIS and directed the Secretary of the Interior to implement a November 18, 2002, ruling. This rule allowed slightly more than half the historic daily snowmobile entries (i.e., 493 sleds per day in YNP), with requirements that all snowmobiles be led by commercial guides. Beginning in winter 2005, snowmobile use would be terminated in favor of multi-passenger snow coaches. Judge Sullivan also ordered the Secretary of the Interior to respond to a 1999 petition by the Blue Water Network asking that snowmobiles be banned and road grooming ceased on National Park Service lands. The Department of the Interior denied this petition on February 17, 2004.

In response to Judge Sullivan's decision, the State of Wyoming and International Snowmobile Association asked Judge Brimmer of the Wyoming Federal District Court to issue a temporary restraining order or preliminary injunction against the National Park

[1] Throughout the report, winters are referred to by their ending year. Thus, the winter extending from November 2003 through April 2004 is referred to as winter 2004.

Service to stop implementation of the November 18, 2002, rule. On February 10, 2004, Judge Brimmer issued a preliminary injunction temporarily restraining the National Park Service from implementing the snowmobile phase-out in Yellowstone and Grand Teton National Parks. Judge Brimmer also required the National Park Service to implement temporary rules for the remainder of the winter 2004 season that were "fair and equitable" to all parties.

On February 11, 2004, Superintendent's Orders for Yellowstone and Grand Teton National Parks were amended to allow continued, managed snowmobile use. Seven hundred and eighty snowmobiles were allowed to enter YNP each day, including 400 sleds through the West Entrance (previously 278 sleds), 220 sleds through the South Entrance (previously 90 sleds), 100 sleds through the East Entrance (previously 65 sleds) and 60 sleds through the North Entrance (previously 60 sleds). The additional 287 snowmobiles allowed by the Superintendent's Order were required to be Best Available Technology snowmobiles. All snowmobiles were required to be commercially guided.

Despite the changes and uncertainty imposed on motorized recreation in YNP during winter 2004 owing to these apparently conflicting legal mandates, we decided to continue the monitoring as planned.

II. METHODS

Conceptual Approach

The collection of reliable information is essential for evaluating the effectiveness of management actions designed to minimize potential adverse effects of winter human use on wildlife. Potential effects to wildlife from winter use may occur at different scales (e.g., individual/group or population) and be characterized as acute (e.g., temporary displacements and acute increases in heart rate or energy expenditures) or chronic (i.e., adversely affect survival). Thus, we collected data at both the individual/group and population scales to assess the potential effects to wildlife from motorized winter use. We also used various measures to evaluate if such effects were likely to contribute to acute or chronic stress of ungulates.

Our recommended approach for monitoring wildlife responses to winter recreation in Yellowstone National Park is as follows:

1. **Define management objectives** for the winter use monitoring program with respect to potential effects of management decisions on wildlife;
2. **Coalesce and integrate information** on the effects of winter human use on wildlife from previous monitoring efforts;
3. **Select key response variables (i.e., indicators)** that will be measured to evaluate the potential effects of human use on wildlife;
4. **Define sampling objectives** for the winter use monitoring program with respect to potential effects of management decisions on wildlife;
5. **Develop, implement, and evaluate sampling and analytical protocols** for estimating wildlife responses to motorized vehicles and human use during winter;
6. **Gain needed sampling design and statistical expertise through collaboration** with a statistician;

7. **Develop long-term objectives and a rigorous monitoring program of key vital signs** that includes data collection, analytical, and reporting protocols and can be implemented over the long term to assess wildlife responses to winter human use;
8. **Communicate our knowledge and discoveries** to resource managers, the scientific community, and visiting public by preparing annual reports, manuscripts, educational presentations, and ideas for interpretive exhibits; and
9. **Review the effectiveness of the monitoring program** every year and, based on the principles of adaptive management, refine the program as necessary.
10. **Employ monitoring results as part of an adaptive management program** to minimize the potential effects of winter human use on wildlife in Yellowstone National Park.

During winter 2004, we collected information to evaluate the following management objectives regarding human use and its potential adverse effects on wildlife during winter in Yellowstone National Park (Attachment A, Table 1, ROD):

- Minimize the avoidance, displacement, or harassment of wildlife from noise, vehicles, or other human activities;
- Minimize vehicle-caused wildlife deaths or injuries;
- Minimize human conflicts with ungulate (e.g., bison, elk) movements on plowed roads;
- Minimize incidents of wildlife trapped by snow berms on plowed roads; and
- Minimize the facilitation of ungulate use of groomed roads.

In addition, personnel from the Superintendents Office (Planning and Compliance) requested that winter use monitoring regarding wildlife specifically address two specific management-related questions: 1) do the responses of wildlife to snowmobiles and snow coaches differ?; and 2) are the levels of human activities and behavioral responses of wildlife different between commercially guided OSVs and other vehicles (e.g., administrative travel, wheeled vehicles)?

Weather Data

We collected weather data from four automated SNOTEL to assess the effects of snow pack on wildlife behavior, distribution, and stress levels. The Madison Plateau (ID 11e31s) and Canyon (ID 10e03s) SNOTEL sites were located within Yellowstone National Park, while the West Yellowstone (ID 11e07s) and Northeast Entrance (ID 10d07s) sites were located near the park's boundary. The West Yellowstone site was located at 6,700 feet elevation, while the Northeast Entrance, Madison Plateau, and Canyon sites were located at 7,350 feet, 7,750 feet, and 8,090 feet elevation, respectively. Data from each site was obtained from the Natural Resources Conservation Service website (http://www.wcc.nrcs.usda.gov/snotel/).

Snow water equivalent (i.e., the amount of water in the snow pack) was either measured or estimated at each SNOTEL site. Snow water equivalent appears to strongly influence where ungulates are located during winter because of increased energy expenditures for movements and accessing forage through snow with higher water content. Ungulates can tolerate higher levels of water in the snow pack early in the winter than later in the winter but, in general, tend to concentrate in areas with lower snow water equivalent as snow pack increases.

Farnes et al. (1999) provided estimates of lower effective critical temperatures for ungulates that inhabit Yellowstone National Park. When ambient temperatures are below these lower effective critical temperatures, animals must increase their basal metabolic rate to maintain body temperature. Lower effective critical temperatures are usually associated with periods having the lowest daily air temperatures, and are typically estimated using captive animals that are resting and undisturbed. We used minimum-temperature data from various SNOTEL sites to estimate the number of days during October through April with temperatures below the effective critical temperatures for bison (i.e., -34^{o}F) and elk (i.e., 0^{o}F) in the park (Farnes et al. 1999).

Motorized Winter Use

We analyzed daily visitation statistics for winter 2004 in coordination with the Visitor Services Office. The Visitor Services Office routinely compiles data from entrance stations, Business Management Office operations, entrance studies, and visitor surveys to determine visitation statistics. Park staff at the west, south, and east entrances recorded numbers and types of OSVs that entered the park each day.

Human Behaviors and Wildlife Responses

Monitoring during winter 2004 followed the methodology and experimental design used during winter 2003, with minor modifications. This enabled us to build upon baseline information collected by biologists from Montana State University and the Resource Management & Visitor Protection Office during 1999 to 2002 (Bjornlie and Garrott 2001, Hardy 2001, Jaffe et al. 2002, unpublished data). This monitoring also provided data regarding bison use of groomed roads that can be compared to similar data collected during recent winters by Montana State University (Bjornlie and Garrott 2001) and the Resource Management and Visitor Protection Office (Reinertson et al. 2002, Jaffe et al. 2002). A brief summary of these studies regarding wildlife responses to motorized winter use in Yellowstone National Park during 1981 to 2002 was provided by Davis et al. (2004:Appendix A).

We focused our efforts on monitoring the responses of bison (*Bison bison*), elk (*Cervus elaphus*), and trumpeter swans (*Olor buccinator*) to motorized winter use vehicles owing to the proximity and/or perceived sensitivity of these species to motorized recreation activities during winter. Three 2-person crews used snowmobiles and wheeled vehicles to conduct repeated surveys of wildlife distribution and responses to motorized winter use vehicles and human activities along nine groomed or plowed road segments. Portions of these road segments that were only open to travel by snow coaches (i.e., Riverside Drive, Freight Road, Firehole Canyon Drive) were also sampled. The sampled road segments and their endpoints were as follows (note: "(C)" denotes snow coach-only portions):

Road Segment	End-point	End-point
1. West Yellowstone to Madison	West entrance station	Madison junction
(C) Riverside Drive	Drive entrance	Drive exit
2. Madison to Old Faithful	Madison junction	Bridge south of Old Faithful
(C) Firehole Canyon Drive	Canyon Drive entry	Canyon Drive exit
(C) Freight Road	Madison-Old Faithful road	Freight Road parking lot
3. Madison to Norris	Madison junction	Norris junction
4. Norris to Mammoth	Norris junction	north end of Swan Lake flats

5. Mammoth to Lamar Valley	High bridge	Round Prairie/Pebble Creek
6. Canyon Village to Lake Butte	Lake Butte	Canyon junction
7. Fishing Bridge to West Thumb	Fishing Bridge	West Thumb
8. West Thumb to South Entrance	West Thumb	South entrance station
9. West Thumb to Old Faithful	West Thumb	Bridge south of Old Faithful

Survey crews were based in Lake, Madison Junction, and Mammoth. The Lake crew sampled the Canyon Village to Lake Butte, West Thumb to South Entrance, West Thumb to Old Faithful and West Thumb to Fishing Bridge road segments. The Madison crew sampled the roads from Madison to West Yellowstone and from Madison to Old Faithful. The Madison road segments included surveying along Riverside Drive, Firehole Canyon Drive, and the Freight Road, all of which are designated for snow coach-only travel. At the request of sub-district law enforcement, the Madison survey snowmobiles were marked with 'Wildlife Research' decals to reduce confusion for visitors and enforcement personnel if snowmobiles were seen on these restricted roads. The Mammoth crew sampled the Norris to Mammoth, Madison to Norris, and Mammoth to Lamar Valley road segments. The Mammoth to Lamar Valley route was surveyed in a 4-wheel drive wheeled vehicle, and the Mammoth to Madison segments were sampled via snowmobile.

Each crew determined the order in which their assigned road segments were sampled using a restricted randomization design. The crew selected the order of monitoring for road segments without replacement, so that each segment was monitored before re-sampling occurred. The direction that a given road segment was traveled by the crew was reversed each time the segment was surveyed. Crews conducted surveys on weekdays, weekends, peak-use periods, low-use periods, and holidays. This sampling design enabled us to record daily and weekly variations in human and wildlife activities. The West Thumb to South Entrance road segment was intentionally sampled less frequently by the Lake crew owing to low numbers of wildlife along this segment and safety concerns (i.e., length of segment and decreased facilities/patrols in case of snowmobile break-down or emergency).

Surveys were only conducted during daylight hours for safety and efficiency reasons. Surveys were conducted by a pair of observers driving snowmobiles at ≤50 kilometers (30 miles) per hour. Beginning and ending times of the survey were recorded as a measure of survey effort. Visibility was categorized as good, fair (i.e., small, patchy areas of low visibility), or poor (large areas of low visibility within 100 meters [110 yards] of the road). Precipitation was categorized as none, light rain, heavy rain, light snow, heavy snow, or fog. If conditions or visibility varied substantially along the road segment, then observers recorded the predominant condition for the segment. While traveling along each road segment, observers used various pullouts and overlooks that provided vantages of wildlife in areas that could not be observed from the main road corridor.

While traveling a given road segment, observers documented the responses of wildlife to motorized winter vehicles and associated human activities. The observers traveled until a group (i.e., ≥1 animal) of a species was detected with the unaided eye. The observers then stopped in a position where they could observe the group without disturbing the animals and observe approaching motorized winter vehicles. The observers recorded the following initial information: 1) time of observation; 2) species; 3) habitat type for the majority of the group (i.e., aquatic, burned forest, unburned forest, wet meadow or riparian, dry meadow, geothermal); and 4) group size and composition (i.e., adult males, adult females, young-of-the-year, unknown).

Our sampling unit was the interaction between motorized vehicles and associated humans and an observed group of wildlife within 500 meters of the road. Though this definition of an "interaction" is somewhat arbitrary, the proposed 500-meter "interaction zone" enabled us to evaluate the influence of distance from a disturbance on wildlife responses to human activities.

After the initial information was recorded, observers determined if any OSVs were approaching the wildlife. If no OSVs were visible within or approaching the 500-meter interaction zone, observers recorded scans of wildlife behaviors in terms of group proportion (e.g., 50% feeding, 20% standing, etc.) at five-minute intervals. This allowed for data collection of "baseline" wildlife behavior when the wildlife group was not in close proximity to human activity. These baseline behavior categories were defined as resting (bed, float), standing (i.e., stand, perch), feeding, traveling (i.e., walk, swim, fly), alarm-attention (vigilance behavior), fleeing (running from a disturbance), or defending (defensive behavior such as charging or grouping). Traveling was defined as animals walking, swimming, or flying in sustained movement. Animals were recorded as resting when they were stationary (i.e., lying, perching, floating). If no OSVs arrived during the 10-minute observation period, observers recorded three scans: 1) one when they initially sighted the group; 2) another five minutes later; and 3) another ten minutes after the initial sighting. If an interaction did not occur within 10 minutes of the observers detecting a group of wildlife within 500 meters of the road, then the observers recorded that no interaction occurred and continued the survey to locate the next group of wildlife.

If OSVs approached, or were already present, within the 500-meter interaction zone, then scans were discontinued to record the wildlife group's response to OSVs and human activity. Motorized winter vehicles could enter the 500-meter zone from either direction along the road corridor. During an interaction, the observers recorded the following information regarding human activity within the interaction zone: 1) number and type of motorized winter vehicles in the group; 2) if the group of motorized winter vehicles stopped within the interaction zone; 3) distance from the stopped motorized winter vehicles to the nearest animal in the group; 4) if the motorized winter vehicle group consisted of administrative operators (e.g., researchers, park staff, etc.) or was led by a commercial guide familiar with the park and its winter regulations. In contrast to winter 2003, all snowmobile groups were guided by trained, commercial operators during winter 2004.

Observers also recorded the numbers of people in a given category of activity during the interactions. Activities were defined as follows:

- No visible reaction to wildlife;
- Stop their OSV, usually to observe or photograph the animals;
- Dismount the motorized winter vehicle (i.e., exit the snow coach or get off the snowmobile);
- Approach the wildlife (i.e., move from the location where the motorized winter use vehicle was parked in the direction of the animals); or

- Impede and/or hasten (e.g., chase wildlife, force animals to move faster ahead of motorized winter vehicle traffic, or block wildlife movement).

The observers also recorded the proportions of response behavior among the animals in the group to the motorized winter vehicle group and associated human activity. Response behaviors were defined as follows:

- No visible reaction to motorized winter vehicles or human activity;
- Look at motorized winter vehicles or human activity and then resume their behavior;
- Travel (e.g., walk/swim) away from motorized winter vehicles or human activity;
- Attention/alarm behavior, including rising from bed or agitation (e.g., buck, kick, bison tail rise);
- Flight (e.g., move quickly (e.g., run) away from motorized winter vehicles or human activity); or
- Defense (e.g., attack/charge at motorized winter vehicles or human activity).

Thus, if two of four animals in a group of elk looked at a group of motorized winter vehicles and resumed feeding, while one elk ran away (i.e., flight), and one elk did not visibly respond, the observers categorized the group's response as 50% look-resume, 25% flight and 25% no reaction. Response behavior was only recorded for those animals within approximately 500 meters of the road. While this methodology allowed for a finer-scale understanding of group reactions to human activity than the 2003 protocol, in which the predominant response of the wildlife group was recorded, group behavior in ungulates and swans tended to be consistent throughout the group. In 76% of the interactions one behavior category (i.e., look-resume, flight, etc.) accounted for 100% of the groups' response.

The observers continued monitoring and recording the interaction until all members of the motorized winter vehicle and/or human group departed the area within 500 meters of the wildlife group. The observers recorded the number, type, and response of all motorized winter vehicles and associated humans that traveled within 500 meters of the wildlife group during the interaction (i.e., until all members of the initial motorized winter vehicle and associated human group departed the area within 500 meters of the wildlife group). No single interaction was monitored for >30 minutes.

Once the survey of a selected road segment was completed, the observers traveled to the next randomly selected road segment and began the next survey. If no animals of species of interest were detected along the selected road segment, then the observers traveled to the next randomly selected road segment and began that survey. Thus, it is possible that the same road segment was sampled more than once per day (e.g., morning and afternoon).

Vehicle-caused Wildlife Deaths or Injuries

We obtained data regarding deaths and injuries of wildlife during the winter use period from the Resource Management and Visitor Protection Office, biologists from the Yellowstone Center for Resources and other sources (e.g., Montana State University).

Energetic Costs and Stress Levels of Wildlife
We followed the methods of Reimers et al. (2003) to obtain a gross estimate of the relative energy costs of interactions with OSVs for elk. Cook (2002:306) estimated the total daily energy expenditure for basal metabolism and activity of an undisturbed, adult female elk weighing 236 kilograms (520 pounds) during winter as 6,456 kilocalories (27,030 kilojoules), or 1.4 times its standard metabolic rate of 4,636 kilocalories (19,410 kilojoules) per day. This estimate was based on elk activity data (Craighead et al. 1973) from the Madison-Firehole drainages before substantial road grooming and motorized winter recreation began in this portion of the park. Thus, the estimate represents the anticipated energy expenditure of an adult female elk during winter in the absence of disturbances by OSVs.

During winter 2004, we recorded the distances moved by elk during interactions with OSVs and calculated the maximum and mean response distances. We estimated energy costs of movement responses on the basis of total horizontal distance moved on medium-soft snow approximately 60 centimeters deep (approximately 70% of the chest height (83 centimeters) of an adult female elk), and an estimated average speed of flight (i.e., traveling) at 1.5 miles (2.4 kilometers) per hour on level terrain. Studies cited in Cook (2002:220) suggest that the net energy cost for elk walking on a firm horizontal surface is approximately 0.62 kilocalories (2.6 kilojoules) per kilogram per kilometer, regardless of the speed at which the animal travels. However, energy costs of locomotion in snow increase exponentially with sinking depth (i.e., percent of chest height), approximately doubling by 60% of chest height. Thus, the net cost of locomotion was estimated as 1.24 kilocalories (5.2 kilojoules) per kilogram per kilometer, with an additional cost of standing of 0.72 kilocalories (3.0 kilojoules) per kilogram per kilometer (Robbins 1993:129 and references cited therein). For example, the energy cost of one kilometer total distance moved for a 236 kilogram adult female elk is locomotion plus standing equals 1,935 kilojoules (locomotion = 5.2 kJ * 236 kg * 1 km = 1,227 kilojoules; standing = 3.0 kJ * 236 kg * 1 km = 708 kilojoules).

The collection of fecal samples and measurement of fecal glucocorticoid levels via radioimmunoassay has been shown to be an effective, non-invasive method to measure physiological stress in elk (Millspaugh 1999, Creel et al. 2002). We collaborated with Dr. Robert Garrott, Montana State University, to collect fecal samples throughout the winter from approximately 25 radiocollared adult female elk in the west-central portion of the park. The ages of these elk were determined by counting of cementum annuli (Hamlin et al. 2000) of a vestigial upper canine tooth extracted at the time the animal was collared. Biologists from Montana State University collected fecal samples from animals after they are observed defecating or by following tracks in the snow behind radiocollared individuals and collecting fresh pellets. Fecal samples were collected in 50 milliliter falcon tubes and stored at approximately –20° Centigrade (–30° Fahrenheit) in a freezer at Montana State University in Bozeman.

Wildlife Abundance
We collaborated with various researchers to estimate the abundance of bison and elk populations during winter 2004. These estimates were used in conjunction with estimates from previous years to evaluate gross trends in abundance since the onset of motorized winter use, and relationships between demographics and winter severity.

Staff from the Bison Ecology and Management Program, Yellowstone Center for Resources, conducted replicate aerial surveys of the bison population to estimate abundance (Hess 2002). In addition, a minimum count of northern Yellowstone elk was obtained during an aerial survey of their entire winter range (both inside and outside the park) on December 18, 2003. The count was conducted by members of the Northern Yellowstone Cooperative Wildlife Working Group (i.e., Montana Fish, Wildlife, and Parks, National Park Service (Yellowstone National Park), U.S. Forest Service (Gallatin National Forest), and U.S. Geological Survey (Northern Rocky Mountain Science Center). Annual winter trend counts of northern Yellowstone elk from aircraft have been conducted on the northern range since 1967.

We also collaborated with Dr. Robert Garrott, Montana State University, to estimate the abundance of elk in the west-central portion of Yellowstone National Park. Telemetry collars were maintained on approximately 25 cow and calf elk in this portion of the park during winter 2004. A continuity-corrected Lincoln-Petersen population estimate (Seber 1982) was calculated for individual surveys 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). Replicate composition surveys were also conducted on 10 consecutive days during the rut in late September and early October. These surveys used the same methodology 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 autumn surveys. We multiplied the proportions of bulls, cows and calves observed during the autumn survey by the previous spring population estimate, and added these estimates together to yield a total population estimate at the onset of winter.

Statistical Analyses

During summer 2003, we developed models to evaluate if variables related to motorized winter use were associated with changes in behavior of bison, elk, and trumpeter swans (Borkowski 2003, Davis et al. 2004). Similar analyses were conducted for the data collected during winter 2004 (Borkowski 2004). The survey and model variables considered in the statistical analyses were as follows: 1) proportions of wildlife response; 2) most extreme wildlife response; 3) most common wildlife response; 4) temperature; 5) cloud cover category; 6) precipitation category; 7) visibility category; 8) habitat type; 9) direction of wildlife travel; 10) perpendicular distance of the nearest animal to the road; 11) number of species; 12) number of adult females; 13) number of adult males; 14) number of young; 15) number of unknown age class; 16) predominant wildlife activity; 17) behavior of undisturbed animals; 18) number of snowmobiles involved in a wildlife interaction; 19) if a snow coach was involved in a wildlife interaction (i.e., presence/absence); 20) number of wheeled vehicles involved in a wildlife interaction; 21) type of guidance associated with the human group (i.e., guided, administrative, wheeled); 22) numbers of human responses during a wildlife interaction; 23) duration of the human/wildlife interaction; 24) most extreme human response; 25) reaction to observer; 26) distance from closest person to animal; 27) total number for the species (i.e., number of animals in the group); 28) total number of snowmobiles involved in a wildlife interaction; 29) daily and cumulative motorized vehicle counts (any gate); 30) daily and cumulative west gate motorized vehicle counts; 31) daily and cumulative south gate motorized vehicle counts; 32) and cumulative east gate motorized vehicle count; and 33) whether the species was on the road during the human/wildlife encounter.

The "wildlife response categories" were the response variables studied in the models. The sampling unit was the wildlife group involved in an interaction with motorized vehicles, not the individual animals within each group. Because of the relatively low frequencies of travel, alarm/attention, flight, and defensive responses, these response categories were combined into a single "active response" category for each species. Hence, there were at least three wildlife response categories considered in the models: no response; look and resume response; and active response. The other variables were potential regression variables whose levels may be associated with certain wildlife responses.

A generalized logits regression model was fit to the data for each species using the CATMOD procedure of the SAS statistical analysis computing package to make two comparisons. First, We evaluated if any of the variables were associated with a significant increase or decrease in a look and resume response relative to no apparent response. Second, he evaluated if any of the variables were associated with a significant increase or decrease in an active response relative to no apparent response.

A generalized logits model is similar to a logistic regression model in the sense that response probabilities are modeled given a set of conditions for the other variables, which can be either categorical (e.g., habitat type) or quantitative (e.g., distance from the road). Three response probabilities were included in the models:

π_{i0} = probability of an active response given condition x_i.
π_{i1} = probability of a look and resume response given condition x_i.
π_{i2} = probability of no response given condition x_i.

In generalized logits regression, the probabilities themselves are not modeled. Rather, the logits (or log odds) are modeled. The number of logits modeled is one less than the number of response levels. Thus, we modeled two logits, L_{i0} and L_{i1}, where:

$$L_{i0} = \log(\pi_{i0} / \pi_{i2}) \quad \text{and} \quad L_{i1} = \log(\pi_{i1} / \pi_{i2})$$

The ratios π_{i0} / π_{i2} and π_{i1} / π_{i2} are also known as odds. For example, if the odds (π_{i0} / π_{i2}) was 2, then response 0 (i.e., active response) was twice as likely to occur than response 2 (i.e., no response) given condition x_i. By selecting π_{i2} to be in the denominator of each odds, these two logits were used to model the following odds ratios: 1) the odds of a wildlife response requiring a low energy expenditure (i.e., look and resume) compared to the odds of a wildlife response requiring negligible or no energy (i.e., no response); and 2) the odds of a wildlife response requiring a higher energy expenditure (i.e., active response) compared to the odds of a wildlife response requiring negligible or no energy. In other words, we assessed whether the odds of a response requiring some energy expenditure relative to the odds of no response was associated with changing levels of the study variables.

Like all statistical regression methods, there are certain assumptions that should be met when using generalized logits regression. First, responses of wildlife groups should be sampled from a large population. We believe that this assumption was met for bison, elk, and swans during the winter season. Second, the sample collected should be random. This assumption was not met because we did not know when or where human/wildlife interactions would occur. Hence, we had no control to randomly select which interactions were observed. Also, the road system used by motorized vehicles was stratified into road segments that were repeatedly sampled through the winter use season. The effects of this deviation from strict random sampling should be negligible given approximately equal effort in sampling each road segment. Third, a predetermined sample of size *n* should be collected. For reasons described above, we could not predetermine our sample size. However, the fact that our sample size was random rather than fixed should not seriously affect the conclusions drawn from the models. Fourth, sampling units should be sampled independently. Our sampling unit was a wildlife group involved in an interaction with motorized vehicles, and we assumed that each sampled wildlife group was independent of every other sampled group. It is quite likely, however, that the same groups, or groups containing subsets of the same animals, were repeatedly sampled. Thus, when modeling the logits, we assume that the effect of this lack of independence on data-based inferences was minimal.

We began the modeling process with a complete model for each species that incorporated all of the variables. In any multiple variable regression, the results of a fitted model are suspect if strong correlations exist among pairs or subsets of variables (known as multicollinearity). Thus, we calculated variance inflation factors to determine if multicollinearity among variables was a potential concern. The only serious multicollinearity problem was between the "distance" (i.e., distance from nearest animal to the road) and "OSVdist" (i.e., distance from closest person to an animal) variables. Thus, only one of these two highly correlated variables should be in the model at any time.

After the complete model was fit, the variable having the largest *p*-value was removed from the model. This model reduction process was continued until all remaining variables had *p*-values less than 0.15. The only exception to this rule was for: 1) the number of snowmobiles; 2) the number of snow coaches; and 3) the guide status for interactions with bison and elk. These variables were retained in the model so that specific management-related questions regarding the comparative effects of snowmobiles versus snow coaches and guide status could be addressed explicitly in the final model. Guide status was not retained in the swan model because there were only three cases of unguided snowmobiles. A maximum likelihood analysis of variance (ML ANOVA) was run to determine if a variable's effect is statistically significant in the generalized logit model.

III. RESULTS

Weather

The snow pack began to accumulate in November, peaked in March, and achieved substantial melt-off by early April in lower elevation areas, though differences among areas of the park were evident. Maximum daily snow water equivalent peaked at approximately 64 centimeters on the Madison Plateau, 35 centimeters at Canyon, 31 centimeters at West Yellowstone, and 18 centimeters at the Northeast Entrance station (Table 1). During early winter (i.e., October and November), average snow water equivalents (i.e., the amount of water in the snow) per month were below averages since 1981. Snow water equivalent values were generally average by late winter, however, with the exception of the northern range area which remained below average throughout the winter (Table 1). Cumulative snow water equivalents during October 1, 2003, through April 30, 2004, were 7,313 centimeters on the Madison Plateau, 2,885 centimeters at West Yellowstone, 3,343 centimeters at Canyon, and 1,552 centimeters at the Northeast Entrance station (Table 1). In summary, the winter of 2004 appeared to be relatively average in terms of cumulative snow water equivalent for the interior portions of the park (Figure 1), but below average for the northern range.

Snow water equivalent appears to strongly influence where ungulates are located during winter because of increased energy expenditures for movements and accessing forage through snow with higher water content. For example, cumulative snow water equivalent during October through April measured at the Northeast Entrance SNOTEL sites was positively correlated with the migration of northern Yellowstone elk to lower elevation areas outside of the park during 1989-2002 (Figure 2). Snow water equivalent has also been related to survival of Yellowstone elk. For example, the number of carcasses detected during spring helicopter surveys of the Gardiner basin in 1989-1997 was positively correlated with cumulative snow water equivalent (Figure 3). Also, the recruitment of elk calves in the central portion of Yellowstone National Park is negatively correlated with cumulative snow water equivalent, with the most severe snow pack conditions resulting in the virtual elimination of a juvenile cohort (Figure 4).

Ambient temperatures during surveys ranged from -12°F to 56°F in the Madison area, -7°F to 55°F in the Lake area, and -20°F to 45°F in the Mammoth area. These data are slightly biased towards higher temperatures due to safety protocols (i.e., surveys were not conducted when the ambient temperature was <-20°F). Generally, winter ambient temperatures in the park were relatively moderate for bison and elk. In the west-central portion of the park, on only one day did the West Yellowstone SNOTEL site record a minimum temperature below the approximate effective critical temperature for bison (i.e., -34°F) during the 213 days from October-April. Forty-six days were below the approximate effective critical temperature for elk (i.e., 0°F). In the northern region of the park, on only 26 days did the Northeast Entrance SNOTEL site record a minimum temperature below the approximate effective critical temperature for elk (0°F) during the 213 days from October-April. No days were recorded below the approximate effective critical temperature for bison (i.e., -34°F)

Motorized Winter Use

The public OSV season was 88 days from December 17, 2003, through March 14, 2004, when all park grooming operations ceased. Plowing operations began at Mammoth Hot Springs on March 8 and progressed southward into the interior of the park. Thus, the arrival of plows and snow removal equipment at each road segment varied.

Total numbers of OSVs that entered each station were as follows (also see Appendix A):

Gate	Guided Snowmobiles	Snow coaches
East Entrance	756	29
North Entrance	NA*	NA
South Entrance	6,330	558
West Entrance	14,704	1,142

Data collected at the North Entrance station did not quantify numbers or types of OSVs brought into the park.

The average and peak daily numbers of total OSVs entering each station were as follows (also see Appendix A):

	Average number of snowmobiles	Average number of snow coaches	Maximum number of snowmobiles	Maximum number of snow coaches
East Entrance	9	<1	35	2
South Entrance	72	6	148	6
West Entrance	167	13	307	27

During winter 2004, the daily number of snowmobiles entering the West Entrance Station did not exceed 550 machines, which was the anticipated daily snowmobile limit for subsequent winters under the 2003 Winter Use SEIS. The numbers of snowmobiles entering the South and East Entrance Stations during winter 2004 did not exceed the anticipated daily snowmobile entry limits for those stations (i.e., South = 250 snowmobiles; East = 100 snowmobiles) under the 2003 Winter Use SEIS.

Hardy (2001) reported that levels of stress hormones in central Yellowstone elk were higher after exposure to >7,500 cumulative vehicles entering the West Entrance Station. This threshold was reached on December 31st during both winters of her study (i.e., 1999, 2000). In contrast, this threshold was reached on January 20th during winter 2003 and February 1st during winter 2004 (Figure 5).

Human Behavior and Wildlife Responses

Monitoring efforts began on December 12, 2003, five days prior to opening for public use, and continued until April 1, 2004, approximately three weeks after the closure of roads to the public for winter use. The budget for monitoring the potential effects of motorized use on wildlife during winter 2004 was $125,000 (Appendix B). Winter use crews conducted 402 surveys of road segments, covering 11,389 kilometers. Observers recorded 4,940 groups of wildlife during these surveys, including 1,087 groups of elk, 2,597 groups of bison, 686 groups of swans, and 570 groups of other species such as bald eagles, coyotes, and wolves. Observers recorded human behaviors and the responses of wildlife to motorized winter vehicles during 3,174 interactions. No groups of wildlife were observed during 22 surveys of road segments. Summaries of observed wildlife groups and interactions by road segment and survey crew are provided in Appendix C.

Groups of snowmobiles and snow coaches were involved in 53% (n = 1,684) and 17% (n = 555), respectively, of the observed wildlife-human interaction events with wildlife during winter 2004. Interactions involving wheeled vehicles accounted for 28% (n = 900) of the observed interactions, while the remaining 2% (n = 35) involved pedestrians and bicyclists. Observers rarely elicited responses from wildlife groups, with the estimated odds of eliciting an active response being <5% the odds of no response.

Human Behaviors: A total of 1,426 interaction events between ungulates (bison and elk) and OSVs (administrative and guided) and associated humans were documented when animal groups were off the roads, including 1,070 groups of snowmobiles and 356 groups of snow coaches. During these interactions, 239 groups of snowmobiles and 76 groups of snow coaches stopped on the road to view animals. Snowmobile riders remained on their machines during 932 interactions, but dismounted during 67 interactions. Snowmobile riders approached wildlife during 39 interactions, and 74% of these people remained >25 meters from animals. Riders in 323 of the snow coaches that stopped stayed in their coaches, while during 33 interactions riders exited the coaches. Snow coach riders approached wildlife during eight interactions, and all of these people remained >25 meters from animals. Interactions observed per kilometer surveyed, and the tendency for riders to dismount or approach wildlife, were similar between winters 2003 and 2004.

We also compared 2,040 observations of human behavior during interactions with bison, elk, and swans among OSVs in commercially guided groups (including snowmobiles and snow coaches) and administrative groups (i.e., park and concessionaire staff) (Appendix D). Generally, the behavior of OSVs and associated humans in response to wildlife groups was relatively minor. Sixty percent of the observed human behaviors towards groups of bison, elk, and swans were categorized as "no visible reaction to wildlife", 24% stopped to observe wildlife while remaining on their snowmobile or inside their coach, 6% dismounted (left their OSVs), 4% approached wildlife, and 6% impeded and/or hastened wildlife. The percentage of people who had no visible reaction to wildlife was similar during winters 2003 and 2004. The tendency for people to stop their OSVs and observe animals was slightly higher during winter 2004, while the numbers of those dismounting/leaving the OSV and approaching wildlife decreased. The percentage of interactions in which OSVs and associated human activity impeded and/or hastened animals increased from 1% in 2003 to 6% in 2004. During winter 2003, snow coaches and snowmobiles accounted for 68% and 32%, respectively, of impede/hasten interactions. During winter 2004, snow coaches and snowmobiles accounted for 22% and 78%, respectively, of the impede/hasten interactions.

Qualitative comparisons (Appendix D) suggest that human behaviors differed among motorized vehicle groups, although complex relationships exist between the variables. For example, there was an apparent tendency for visitors in commercially guided snowmobile groups to pass by wildlife without stopping (categorized as "no reaction", 70%), whereas administrative groups stopped as often as they passed by without stopping (45% and 43%, respectively). Seven percent of guided snowmobilers approached wildlife, compared to only 1% of administrative snowmobilers. Also, there was an apparent tendency for visitors in wheeled vehicles on the plowed road segment between Mammoth and Cooke City to respond less often to groups of wildlife than visitors on OSVs. The proportions of guided (5%) and administrative (7%) OSVs that impeded or hastened wildlife were similar.

Wildlife Responses: Generally, the responses of most wildlife species to OSVs and associated humans were typically minor, with 58% (n = 1,296) of the 2,239 predominant responses of wildlife responses categorized as no apparent response, 18% (n = 410) look/resume, 11% (n = 252) attention/alarm, 9% (n = 196) travel, 4% (n = 82) flight, and <1% (n = 3) defense (Appendix E). Wildlife responses to motorized winter use were consistent across species, with the "no apparent response" and "look-and-resume" categories accounting for 84%, 60%, and 56% of the bison, elk, and swan observations (Borkowski 2004).

The magnitude of the responses varied considerably among species, with the likelihood of observing an active response to snow coaches or increasing numbers of snowmobiles in a group being similar for bison and swans, but significantly higher for elk (Borkowski 2004). The estimated odds of observing an active response relative to no response by bison were 14% greater for each additional snowmobile in the group (up to 12 snowmobiles) and 2.3 times greater if a snow coach was in the group. Thus, under identical conditions, we would expect the odds of an active bison response (relative to the odds of not response) to be, on average, 28% higher for a group of four snowmobiles that for a group of two snowmobiles. Likewise, the odds of observing an active response relative to no response by swans were 13% greater for each additional snowmobile in the group (up to 8 snowmobiles) and 2.2 times greater if a snow coach was in the group. In contrast, the odds of observing an active response relative to no response by elk were 4.4 times greater for each additional snowmobile in the group (up to 2 snowmobiles) and 18.4 times greater if a snow coach was in the group.

Wildlife responses varied by species among commercially guided, administrative, and wheeled groups during winter 2004 (Borkowski 2004). For example, wheeled vehicles elicited substantially fewer active responses by bison or elk than either administrative or guided groups of OSVs. Also, the estimated odds of observing an active response compared to no response by bison or elk were significantly higher for administrative traffic than for guided OSVs. This finding appeared to be due to an increased tendency for administrative vehicles to stop more often in the vicinity of wildlife and to impede/hasten wildlife more frequently. At this time, however, we cannot satisfactorily explain why administrative traffic would stop more frequently, nor can we discount that this apparent result may be spurious owing to relatively small sample sizes obtained during a single winter.

Several other variables likely influence the odds of a response by bison, elk, and/or swans to motorized winter use, including group size and composition, habitat type, human activity, precipitation, visibility, wildlife activity (e.g., standing v. bedded), ambient temperature, interaction time, and daily numbers of motorized vehicles entering the park (Borkowski 2004). For example, the estimated odds of an active response relative to no response increase with the number of juveniles in a bison or elk group, but decrease as the number of adult males increase. Also, the estimated odds of observing an active response relative to no response were 3-5 times greater when the predominant activity of an undisturbed group of bison was traveling rather than resting. Moreover, for each minute increase in interaction time (up to 20 minutes), the estimated odds of observing an active response by bison were 5% higher than the odds of observing no response. By analyzing data collected over several winter seasons, the influence of these variables on wildlife responses can be reexamined with an increased sample size; thereby providing better inference.

Small samples of predator species groups were observed during our surveys. Wolves were observed on 14 occasions and during 11 interactions with motorized winter vehicles and associated humans. Wolves traveled away from humans in two interactions (18%) and fled humans in one interaction (9%). Coyotes were observed on 214 occasions and during 140 interactions with motorized winter vehicles and associated humans. Coyotes traveled away from humans in 27 interactions (19%), fled humans in 13 interactions (9%), and displayed alarm in 4 interactions (3%). Otters were observed on 12 occasions and during 8 interactions with motorized winter vehicles and associated humans. Otters were minimally affected (i.e., no reaction or look-resume) during those interactions, with the exception of one instance in which an otter fled from human activities. No bobcats, lynx, or mountain lions were observed during our surveys.

Human Conflicts with Ungulate Movements on Plowed Roads: Wildlife were observed on the plowed road from Mammoth to the Northeast Entrance on 60 occasions during our surveys, including 35 bison groups, 20 coyote groups, four elk groups, and one wolf group. Wildlife were not trapped by, or forced to jump over, snow berms along the sides of the road during any of these observations. Also, nine interactions were recorded on interior roads after plowing operations had cleared those roads for administrative traffic. Eight of these interactions occurred in the Madison district, and six interactions resulted in wheeled vehicles impeding or hastening wildlife.

Ungulate Use of Groomed Roads: Bison were observed on groomed roads during 311 of 2,597 observations of bison groups from December 12, 2003, through April 1, 2004. Thus, the vast majority of observed bison groups were using areas off the groomed roads. Bison use of groomed roads occurred throughout the daylight survey hours, with no apparent peak time of road use (Figure 6).

Elk were observed on groomed roads during 30 of 779 observations of elk groups from December 12, 2003, through April 1, 2004. Thus, the vast majority of observed elk groups were using areas off the groomed roads and, similar to winter 2003 elk were observed using groomed roads less than bison.

A total of 228 interaction events between ungulates and OSVs and associated humans were documented when animal groups were <u>on</u> the groomed roads, including 170 groups of snowmobiles and 58 groups of snow coaches. Thirty-three percent of these snowmobile groups impeded or hastened wildlife movement. Two of these observations involved animals jumping roadside berms to avoid snowmobile traffic. Similarly, 33% of these snow coach groups impeded or hastened wildlife movement. The estimated odds of observing an active response by bison relative to no response were 212 times higher for an impede/hasten response than for no human response.

Wildlife Distances from Roads: We recorded numbers of animals and distances from roads for the nearest animal in 2,295 groups of bison, 1,087 groups of elk, and 685 groups of swans. Mean distances to the nearest animal in bison, elk, and swan groups from roads were 170, 148, and 120 meters, respectively. On average, swans were observed closer to roads because the road systems are typically located close to rivers. However, wildlife groups located closer to motorized winter use corridors exhibited increased responses to OSV traffic and associated human behaviors (Figure 7). Behavioral responses of wildlife decreased as distance from motorized winter use corridors increased. The estimated odds of observing no response relative to an active response by bison, elk, and swans was significantly higher for each 100-meter increase in distance from the road (up to 200 meters for bison and elk, and 75 meters for swans).

Vehicle-caused Wildlife Deaths or Injuries
During December 2003 to late March 2004, 10 animals were either killed directly during collisions with wheeled vehicles or euthanized as a result of such collisions. This total included two elk and one owl in the Mammoth area, three coyotes and one bighorn sheep in the Lamar Valley, and two elk and one wolf in the Tower area. We are not aware of any wildlife deaths during winter 2004 owing to collisions with OSVs.

Energetic Costs and Stress Levels of Wildlife
The maximum distance moved by an elk provoked by OSVs and associated humans into travel or flight was 220 meters. Thus, the approximate energy cost of a single provocation by OSVs and associated humans, during which the animal left the immediate area, was approximately 426 kilojoules. This energy cost represents an energy increment of approximately 1.5% of the total daily energy expenditure (27,030 kilojoules) for basal metabolism and activity of an undisturbed, adult female elk weighing 236 kilograms during winter. Accumulated energy costs of three such responses to provocations would average <5% of total daily energy expenditure. However, it is unlikely that this many travel or flight responses would occur for a given animal during a day. Such responses were only observed during <10% of interactions between elk groups and OSVs, and evidence suggests that animals habituate to increasing OSV traffic within and among days. Thus, it is unlikely that many elk incur moderate energy costs from human provocations. These moderate energy costs should be easily compensated for, and will most likely not have any demographic consequences (Reimers et al. 2003).

Technicians from Montana State University (Dr. Robert Garrott) collected fecal samples from approximately 25-35 radio-collared elk of known ages in west-central portion of Yellowstone National Park during winters 2001, 2003, and 2004. We intend to contract Dr. Scott Creel, Montana State University, to extract the fecal samples and determine nanograms of corticosterone excreted per gram of dry feces using the double-antibody [125I] corticosterone radioimmunoassays (Creel et al. 2002). These analyses were to be completed by during 2003, but were delayed by laboratory and logistic constraints. The results of the analyses will be compared to similar samples collected during winters of 1999 and 2000 (Hardy 2001, Creel et al. 2002) to evaluate the potential for chronic stress of ungulates in areas with relatively intensive motorized winter use.

Wildlife Abundance
Abundance of the central Yellowstone elk population was estimated at 398 elk in April 2002, 384 elk in April 2003, and 261 elk in April 2004. The autumn elk population in 2003, as estimated by combining the mean spring estimate for 2003 with the autumn sex-age composition survey, was 486 elk. This estimate is comparable to those obtained by various researchers during 1965-2001 (Craighead et al. 1973, Aune 1981, Eberhardt et al. 1998, Garrott et al. 2003), suggesting that this population has been maintained in a dynamic equilibrium for at least three decades (Figure 8, Garrott et al. 2003).

A total of 8,335 northern Yellowstone elk were counted during a December 18, 2003, survey. Approximately 75% of the observed elk were located within Yellowstone National Park, while 25% were located north of the park boundary. The long-term trend in counts of northern Yellowstone elk suggests that the population has decreased since 1988 (Figure 9). Factors that contributed to this overall decreasing trend likely include predation, drought-related effects on pregnancy and calf survival, periodic substantial winter-kill owing to severe snow pack, and human harvest. There is no evidence that motorized use contributed to this decreasing trend.

Staff from the Bison Ecology and Management Program, Yellowstone Center for Resources, estimated the abundance of bison in Yellowstone National Park at approximately 3,600 bison (95% CI = 2,855-4,352) based on two replicate aerial surveys (Hess 2002) during February 20-21, 2004. The growth rate of the bison population during 1997-2003 averaged approximately 13% per year after accounting for removals (Figure 10).

IV. Discussion

Snow pack and ambient temperatures during winter 2004 were approximately average in the interior portions of the park, but below average on the northern range. Thus, environmental conditions for wildlife were moderate during winter 2004, despite the continued drought that likely reduced forage availability somewhat. Also, the frequency and intensity of motorized use by visitors was relatively low compared to previous winters. This lower visitation resulted, in part, from court orders in December and February and the accompanying uncertainty imposed on motorized recreation in the park. Approximately 16,000 OSVs entered the park's west entrance during winter 2004, compared to >22,000 OSVs during winter 2003 (which was also a relatively low visitation winter owing to poor snow pack). The cumulative total of OSVs entering the West Entrance Station surpassed 7,500 vehicles on February 1, 2004, compared to January 20th during winter 2003 and December 31st during the winters of 1999 and 2000.

The behavior of OSVs and associated humans in response to wildlife groups during winter 2004 was typically minor, with 60% of the 2,040 total observed human behaviors to groups of bison, elk, and swans categorized as no visible reaction to wildlife, 24% stop to observe wildlife while remaining at their vehicles, 6% dismount their vehicles, 4% approach wildlife, and 6% impede and/or hasten wildlife. Human responses during winter 2003 were also relatively minor, with 59% of the 1,315 total observed human behaviors to groups of bison, elk, and swans categorized as no visible reaction to wildlife, 18% stop and observe, 13% dismount OSVs, 8% approach wildlife, 1% impede and/or hasten wildlife, and 1% undetermined (Davis et al. 2004). Similar to winters 2002 and 2003, the behaviors of visitors associated with snowmobiles or snow coaches were generally similar (Jaffe et al. 2002, Davis et al. 2004). One exception is that during winter 2003 snow coaches accounted for 68% of impede/hasten interactions, whereas during winter 2004 snowmobiles accounted for 78% of the impede/hasten interactions. However, this apparent result may be spurious owing to relatively small sample sizes each year for this type of behavior.

The responses of wildlife to OSVs and associated humans during winter 2004 were typically infrequent, short in duration, and of minor to moderate intensity. Sixty-two percent of the 2,040 total observed responses by groups of bison, elk, or swans were categorized as no apparent response, 15% look/resume, 12% attention/alarm, 9% travel, 2% flight, and <1% defense. Responses to motorized winter use were consistent across bison, elk, and swans, but the magnitude of the responses varied considerably among species. The likelihood of observing an active response to snow coaches or increasing numbers of snowmobiles in a group was similar for bison and swans, but significantly higher for elk.

These results were similar to those reported by Aune (1981), Hardy (2001), Jaffe et al. (2002), and Davis et al. (2004). For example, the "no apparent response" and "look-and-resume" categories accounted for 91%, 74%, and 81% of the bison, elk, and swan responses to OSVs, respectively, during winter 2003 (Davis et al. 2004). Similarly, Hardy (2001) reported that 82% of bison and elk groups observed during surveys of road segments along the Madison and Firehole River drainages in the winters of 1999 and 2000 exhibited no apparent response to OSVs. Fifteen percent of the groups that exhibited a detectable response merely looked at the OSVs and associated humans and resumed their activity (i.e., "look-and-resume"). Likewise, Jaffe et al. (2002) reported that 87% of the 25,173 animals observed during surveys of road segments along the Madison and Firehole River drainages in the winter of 2002 exhibited no apparent response to OSVs. Sixty-eight percent of the animals that exhibited a detectable response merely looked at the OSVs and associated humans and resumed their activity.

The frequency and intensity of responses of bison and elk to motorized winter use in Yellowstone National Park during winters 2003 and 2004 were relatively minor and infrequent compared to several other studies of human disturbance. For example, Fortin and Andruskiw (2003) reported that bison in Prince Albert National Park, Saskatchewan, Canada, reacted to human presence by approaching (3%), looking while remaining in place (46%), or fleeing the area (51%). Bison were as likely to flee from a person on foot as a snowmobile, and the probability of flight by groups that included young bison (<1 year old) increased as the snowmobile got closer, reaching 50% at 257 meters. Similarly, bison, mule deer (*Odocoileus hemionus*), and pronghorn (*Antilocapra americana*) at Antelope Island State Park, Utah, exhibited a 70% probability of flushing from on-trail hikers or mountain bikers when the animals were <100 meters from the trail (Taylor and Knight 2003).

The relatively infrequent and lower intensity responses to provocation by bison and elk in Yellowstone National Park suggest that they have habituated somewhat to motorized winter use and associated humans. Habituation occurs when an animal learns to refrain from responding to repeated stimuli that are not biologically meaningful (Eibl-Eibesfeldt 1970). Wildlife may become conditioned to human activity when the activity is controlled, predictable, and does not harm the animals (Hardy 2001, Schultz and Bailey 1978, Thompson and Henderson 1998).

Mean distances of bison and elk groups from groomed road segments did not indicate avoidance of the road as motorized use increased, and the probability that either bison or elk would respond to OSVs decreased as motorized use increased (Hardy 2001, Davis et al. 2004). During winter 2004, the estimated odds of observing no response relative to an active response on a given day were 23% and 79% higher in bison and elk, respectively, for each 100-vehicle increase. These results suggest that ungulates are less likely to respond on days with higher traffic, likely due to some sort of habituation to the relatively continuous traffic. The incentive of available food, in conjunction with frequent and predictable patterns of vehicular traffic without direct negative impacts such as human hunting pressure, may induce habituation by bison and elk to motorized winter use (Hardy 2001).

Aune (1981) also concluded that wildlife habituated to the presence and patterns of human activity in the upper Madison River drainage of Yellowstone National Park. Motorized winter visitation during winters 2003 and 2004 was still approximately twice as high as during Aune's (1981) study, even though visitation during these years was 25% and 62% less than the 10-year average, respectively. Despite this increased exposure motorized winter use, bison and elk have continued to utilize the same core winter range during the past three decades. For the most part, OSVs travel through the study area in predictable and regular fashion, remaining confined to roads and, typically, without humans threatening or harassing elk and bison. Few people venture far from roads, established trails, or areas of concentrated human activities (e.g., warming huts, geyser basin trails). These characteristics of winter recreation likely facilitate behavioral habituation by wintering bison and elk to motorized vehicle traffic (Hardy 2001). Hence, winter recreation activities should continue to be conducted in a predictable manner that allows animals to habituate to motorized vehicles and associated human activities.

Despite this apparent habituation, any human activity in close proximity provoked behavioral responses from wildlife. Similar to Hardy (2001) and Davis et al. (2004), we found an increase in behavioral responses by ungulate groups to motorized use as the distance from groomed roads decreased. Few responses occurred when wildlife were more than 100 meters from the groomed road, and no active responses were recorded when bison and elk were >200 meters from the road or swans were >75 meters from the road. In addition, Jaffe et al. (2002) reported that 17% of animals within 100 meters of the road (n = 17,209) responded to stopped OSVs, whereas only 3% of the 7,924 animals observed farther than 100 meters from the road (n = 297) visibly responded to the presence of OSVs. The closer bison and elk were to any type of human activity, including vehicular travel on roads, the more likely they were to behaviorally respond. Aune (1981) documented similar instances, and Dorrance et al. (1975) reported that white-tailed deer exposed to heavy snowmobile traffic on the weekends and lighter snowmobile traffic during week days were sighted near trails less often on days with higher snowmobile traffic volumes. Fortin and Andruskiw (2003) suggested that humans could minimize their effects to bison in Prince Albert National Park, Saskatchewan, Canada, by remaining farther than 260 meters from herds and being discreet when near large herds containing young bison.

We have not conducted detailed energetics modeling to evaluate the relative energy costs of interactions with OSVs for wildlife compared to their total daily energy expenditures; primarily because such exercises require numerous assumptions and parameter estimates that are not well defined, but could strongly influence model output (Beissinger and Westphal 1998). However, several independent studies of the responses of wildlife to OSVs and associated humans in Yellowstone National Park (Hardy 2001, Jaffe et al. 2002, Davis et al. 2004) have consistently reported that behavioral responses were relatively infrequent, short in duration, and of minor to moderate intensity. This suggests that animals exposed to OSVs typically do not incur a substantial energetic cost from such interactions, even if provocations are repeated throughout the day. Gross estimates of the additional energy costs of travel or flight responses provoked by OSVs were relatively minor to moderate for elk, and likely easily compensated for without any significant demographic consequences. Similar findings were reported for wild reindeer (*Rangifer tarandus*) in southern Norway responding to direct provocation by snowmobiles or skiers (Reimers et al. 2003), even though the mean flight distances of 660-970 meters for reindeer were approximately 3-4 times greater than the maximum distance moved by elk after provocation during our winter 2004 monitoring. Minor energetic costs of human disturbance would especially be expected if animals habituate to OSVs within and among winters, as appears to be the case for bison and elk in the most intensively used OSV corridors in Yellowstone National Park.

Approximately 90% of the bison groups observed during winters 2003 and 2004 were using areas off the groomed roads. Bison use of groomed roads occurred throughout the daylight survey hours, with no apparent peak time of road use. Elk groups were observed using groomed roads less than bison during both winters. These results were similar to those reported by Bjornlie and Garrott (2001) and Reinertson et al. (2002). Bjornlie and Garrott (2001) made 28,293 observations of bison groups in the Madison, Gibbon, and Firehole drainages of Yellowstone National Park during 1998 and 1999. Bison road use was minimal compared to off-road areas and negatively correlated with grooming, with a peak of bison road use in April and lowest use during the period of road grooming operations (Bjornlie and Garrott 2001). Reinertson et al. (2002) recorded 13,845 observations of bison locations and travel patterns (approximated by tracks) in relation to groomed road surfaces during 1997-2002. Reinertson et al. (2002) supported the findings of Aune (1981) and Bjornlie and Garrott (2001) that bison use of groomed roads was minimal, but cautioned that road use by bison was highly variable and that a 5-year study was not sufficient to make management decisions.

Bjornlie and Garrott (2001) reported that 60% of encounters between bison and OSVs when bison were traveling on the groomed snow roads in the upper Madison drainage during the winters of 1998 and 1999 resulted in negative reactions. During winter 2004, we observed that snowmobile and snow coach groups impeded or hastened wildlife movement during 33% and 33%, respectively, of interactions when animal groups were on the groomed roads. Likewise, during winter 2003 snowmobile and snow coach groups impeded or hastened wildlife movement during 13% and 25%, respectively, of interactions when animal groups were on the groomed roads. Similar to Bjornlie and Garrott (2001), we occasionally observed animals being moved by OSVs along extended distances of groomed road (maximum = 800 meters) or into deep snow off the road in order to avoid the activity. We did not observe ungulates trapped by, or forced to jump over, snow berms along the sides of the plowed road from Mammoth to the Northeast Entrance during any observations in winters 2003 or 2004.

During winter 2004, 10 animals were killed by wheeled vehicles, but none were killed by OSVs. In contrast, 11 animals were killed by snowmobiles ($n = 7$) and wheeled vehicles ($n = 4$) during winter 2003. No animals were reported killed by snow coaches during either winter. In a previous study of vehicle-associated mortality in Yellowstone National Park, Gunther et al. (1999) reported that when road days available to each vehicle type was standardized, wheeled vehicles struck wildlife at a significantly higher frequency than snowmobiles. Bison had the highest proportion of snowmobile-caused deaths (i.e., approximately 9%). Gunther et al. (1999) also indicated that no records exist in which a snow coach struck and killed a large mammal.

The fundamental biological question regarding human winter use in Yellowstone National Park is how does winter recreation affect the fitness and survival of bison and elk? Abundance estimates indicate that numbers of bison wintering in areas of motorized winter use have increased since this type of winter recreation was initiated in the 1960's. Likewise, abundance estimates for elk in west-central Yellowstone, which is an area with relatively intense motorized winter use, have remained relatively stable over the past 30 years (Hardy 2001, Jaffe 2001, Garrott et al. 2003). These bison and elk winter in the same areas each year, despite increased OSV use since the late 1970's. In other words, these populations have coexisted with motorized winter use without a decrease in abundance. Thus, any adverse effects of motorized winter use to ungulates have apparently been compensated for at the population level. Fortin and Andruskiw (2003) reached a similar conclusion for bison in Prince Albert National Park, Saskatchewan, Canada. They found no evidence that the frequency of disturbance imposed on bison by snowmobiles, trucks, or foot traffic had an important effect on resource use or bison density among meadows.

Furthermore, the statistical models developed by Hardy (2001) to evaluate if motorized winter use contributed bison and elk distribution, behavior, and stress hormone levels yielded low R^2 values, suggesting that statistically significant variables in these models had little biological consequence overall. Thus, it is unlikely that significant, adverse, population-level effects to ungulates from motorized winter use will be detected in the future owing to the dominating effects of winter severity, predator off-take (including restored wolves), and human removals on the demographics of these populations. Similarly, Fortin and Andruskiw (2003) reported that bison density and distribution in Prince Albert National Park, Saskatchewan, Canada was related primarily to environmental factors such as snow depth during winter, rather than frequency of disturbance imposed on bison by snowmobiles, trucks, or foot traffic.

Based on these population-level results, we suggest that the debate regarding effects of human winter recreation on wildlife in Yellowstone National Park is largely a social issue as opposed to a wildlife management issue. Effects of winter disturbances on ungulates from motorized and non-motorized uses likely accrue more at the individual animal level (e.g., temporary displacements and acute increases in heart rate or energy expenditures) than at the population scale. The positive correlation between locations of large wintering ungulate herds and winter recreation suggests a general tolerance of wildlife to human activities. Habituation to human activities, especially if these activities remain generally predictable, likely lessens the chance for chronic stress or abandonment of critical wintering habitats that could have significant population-level effects. Thus, the level of tolerance by certain constituencies (including park staff) for observed negative interactions between OSVs and wildlife (e.g., impede/hasten responses) may be more of an issue than the actual effects of such interactions on wildlife.

V. RECOMMENDATIONS

Monitoring results during winters of 2003 and 2004 suggest that several aspects of human behavior associated with motorized winter use could be modified through adaptive management to lessen the frequency of possible disturbances to wildlife. We recommend that training for guides, park staff, and concessionaires include the following voluntary recommendations: 1) stop at distances >100 meters from groups of wildlife, when possible; 2) reduce the frequency of multiple groups of motorized vehicles stopping in the same area to observe wildlife (i.e., reduce group size of motorized vehicles); 3) reduce the number of stops to observe wildlife and human activities away from vehicles during these stops; and 4) reduce interaction time because the likelihood of an active response by wildlife increases with longer interaction times. This training is essential because recreationalists often perceive that it is acceptable to approach wildlife more closely than empirical data indicates wildlife will tolerate (Taylor and Knight 2003). Because bison and elk behaviorally respond to people deviating from known, predictable routes, management measures that encourage visitors to stay on roads and established trails should also reduce wildlife disturbance rates.

In collaboration with professors from Montana State University, we are currently analyzing a combined data set collected by various researchers during 1999-2004 regarding wildlife responses to motorized winter use in Yellowstone National Park. The objectives of those analyses are to evaluate potential indicator variables of wildlife responses to human winter use, identify key conditions leading to responses, quantify variations in the frequencies of responses, and estimate thresholds for the most important disturbance factors. Thus, we expect to have completed a thorough analysis of the behavioral responses of wildlife to OSVs by winter 2005.

Given the consistent findings of behavioral response studies to date, and the relatively low power to detect statistically significant changes in wildlife responses in the near future, we recommend some substantive changes in the focus of winter use monitoring for wildlife during winter 2005. First, we recommend focusing the behavioral sampling of wildlife responses to OSVs in the Madison-Firehole drainages, while ceasing such monitoring throughout the remainder of the park. This approach will enable us to maintain continuity in behavioral sampling in the area of most intensive OSV use, while providing us to with more logistical flexibility to begin focusing other issues of importance. Second, we recommend using field crews to sample and map bison travel vectors (i.e., trail systems) in the west-central portion of the park, including the Madison-Firehole drainages and Hayden and Pelican Valleys. These data can be used to evaluate the effects of road grooming on use of roads by bison. We have collaborated with researchers from Montana State University (Robert Garrott) and California State University-Monterey Bay (Fred Watson and Susan Alexander) to develop conceptual models of bison movement through the park based on remotely sensed landscape features (e.g., vegetation, terrain, and geothermal maps), snow pack measurements and modeling, and bison distribution data. These models have been used to predict how bison move through the landscape based on environmental and energetic constraints. These models accurately predict the distributions of bison on the landscape given varying environmental conditions, but we need to verify that the models are accurately predicting movement systems by collecting field data of actual trails. If the models predict bison trail systems and movements accurately, then we can compare model predictions of bison movement based on based on environmental constraints with the existing groomed road system to evaluate how grooming has affected bison movements. Third, we recommend the collection of snow-urine samples from northern and central Yellowstone ungulates to assess nutrition using the methodology described by Pils (1997). This information will enable us to better assess energetic costs and physiological consequences of various environmental conditions, interactions with OSVs, and road grooming.

VI. LITERATURE CITED

Aune, K.E. 1981. Impacts of winter recreationists on wildlife in a portion of Yellowstone National Park, Wyoming. Unpublished M.S. thesis. Montana State University, Bozeman.

Beissinger, S. R., and M. I. Westphal. 1998. On the use of demographic models of population viability in endangered species management. Journal of Wildlife Management 62:821-841.

Bjornlie, D.D., and R.A. Garrott. 2001. Ecological effects of winter road grooming on bison in Yellowstone National Park. Journal of Wildlife Management 65:423-435.

Borkowski, J.J. 2003. Evaluating wildlife responses to winter human use in Yellowstone National Park: a statistical analysis of the bison, elk, and trumpeter swan winter use wildlife road survey data, December 2002 to April 2003. Copy of unpublished report dated September 8, 2003, on file at the Yellowstone Center for Resources, Yellowstone National Park, Wyoming.

Borkowski, J.J. 2004. Evaluating wildlife responses to winter human use in Yellowstone National Park: a statistical analysis of the bison, elk, and trumpeter swan winter use wildlife road survey data, December 2003 to April 2004. Copy of unpublished report dated May 28, 2004, on file at the Yellowstone Center for Resources, Yellowstone National Park, Wyoming.

Cook, J.G. 2002. Nutrition and food. Pages 259-349 *in* D. E. Toweill and J. W. Thomas, editors. North American Elk: Ecology and Management. Smithsonian Institution Press, Washington, D.C.

Craighead, J.J., F.C. Craighead, Jr., R.L. Ruff, and B.W. O'Gara. 1973. Home ranges and activity patterns of nonmigratory elk of the Madison drainage herd as determined by biotelemetry. Wildlife Monograph No. 33.

Creel, S., J.E. Fox, A. Hardy, J. Sands, B. Garrott, and R.O. Peterson. 2002. Snowmobile activity and glucocorticoid stress responses in wolves and elk. Conservation Biology 16:809-814.

Davis, T.D., P.J. White, J. Borkowski, D. Reinhart, C. McClure, and P. Perotti. 2004. Wildlife responses to motorized winter recreation in Yellowstone National Park. Unpublished report dated January 12, 2004, and on file at the Yellowstone Center for Resources, Yellowstone National Park, Mammoth, Wyoming.

Dorrance, M.J., P.J. Savage, and D.E. Huff. 1975. Effects of snowmobiles on white-tailed deer. Journal of Wildlife Management 39:563-569.

Eberhardt, L.L., R.A. Garrott, P.J. White, and P.J. Gogan. 1998. Alternative approaches to aerial censusing of elk. Journal of Wildlife Management 62:1046-1055.

Eibl-Eibesfeldt, I. 1970. Ethology: The Biology of Behavior. Holt, Rinehart, and Winston, New York, New York.

Farnes, P., C. Heydon, and K. Hansen. 1999. Snowpack distribution across Yellowstone National Park. Unpublished Final Report (Proposal No. 97-447; Cooperative Agreement No. CA1268-1-9017; Grant and Contract No. 291601) by Montana State University, Bozeman, submitted to the Yellowstone Center for Resources, Yellowstone National Park, Wyoming, December 1999.

Fortin, D., and M. Andruskiw. 2003. Behavioral response of free-ranging bison to human disturbance. Wildlife Society Bulletin 31:804-813.

Garrott, R.A., L.L. Eberhardt, P.J. White, and J. Rotella. 2003. Climate-induced variation in vital rates of an unharvested large-herbivore population. Canadian Journal of Zoology 81:33-45.

Gunther, K.A., M.J. Biel, R.A. Renkin, and H.N. Zachary. 1999. Influence of season, park visitation, and mode of transportation on the frequency of road-killed wildlife in Yellowstone National Park. Unpublished report on file at the Bear Management Office, Yellowstone Center for Resources, Yellowstone National Park, Mammoth, Wyoming.

Hamlin, K.L., D.F. Pac, C.A. Sime, R.M. DeSimone, and G.L. Dusek. 2000. Evaluating the accuracy of ages obtained by two methods for Montana ungulates. Journal of Wildlife Management 64:441-449.

Hardy, A.R. 2001. Bison and elk responses to winter recreation in Yellowstone National Park. Unpublished M.S. thesis. Montana State University, Bozeman.

Hess, S.C. 2002. Aerial survey methodology for bison population estimation in Yellowstone National Park. Unpublished Ph.D. dissertation. Montana State University, Bozeman.

Jaffe, R. 2001. Winter wolf predation in an elk-bison system in Yellowstone National Park, Wyoming. Unpublished Master of Science thesis. Montana State University, Bozeman.

Jaffe, R., D. Elwood, A. Dimmick, T. Davis, and C. McClure. 2002. Final report: wildlife road survey and human interactions on and off road. Copy available from the West District Resource Management Office, Yellowstone National Park, Wyoming.

Millspaugh, J.J. 1999. Behavioral and physiological responses of elk to human disturbances in the southern Black Hills, South Dakota. University of Washington, Seattle.

National Park Service. 2003*a*. Record of Decision for Winter Use Plans – Supplemental Environmental Impact Statement for Yellowstone and Grand Teton National Parks and the John D. Rockefeller Jr., Memorial Parkway. National Park Service, U.S. Department of the Interior.

National Park Service. 2003*b*. Final Supplemental Environmental Impact Statement for Winter Use Plans – Yellowstone and Grand Teton National Parks and the John D. Rockefeller Jr., Memorial Parkway. National Park Service, U.S. Department of the Interior.

Pils, A.C. 1997. Sampling and analysis methods for snow-urine nutritional assays. Unpublished Master of Science thesis. Montana State University, Bozeman.

Reimers, E., S. Eftestol, and J.E. Colman. 2003. Behavior responses of wild reindeer to direct provocation by a snowmobiler or skier. Journal of Wildlife Management 67:747-754.

Reinertson, E., D. Reinhart, and G. Kurz. 2002. Winter bison monitoring 2002 annual report. Unpublished report dated April 26, 2002. Copy on file at the Yellowstone Center for Resources, Yellowstone National Park, Wyoming.

Rice, W.R., and J.D. Harder. 1977. Application of multiple aerial sampling to a mark-recapture census of white-tailed deer. Journal of Wildlife Management 41:197-206.

Robbins, C.T. 1993. Wildlife Feeding and Nutrition. Academic Press, New York, New York.

Schultz, R.D., and J.A. Bailey. 1978. Responses of national park elk to human activity. Journal of Wildlife Management 42:91-100.

Seber, G.A.F. 1982. The estimation of animal abundance. MacMillian, New York, New York.

Taylor, A.R., and R.L. Knight. 2003. Wildlife responses to recreation and associated visitor perceptions. Ecological Applications 13:951-963.

Thompson, M.J., and R.E. Henderson. 1998. Elk habituation as a credibility challenge for wildlife professionals. Wildlife Society Bulletin 26:477-483.

Table 1. Snow-water equivalents (SWE) measured (centimeters) at four SNOTEL sites in or near Yellowstone National Park, Wyoming. Cumulative SWE was computed by summing daily values from October 1st through the end of each month.

SNOTEL Data	OCT	NOV	DEC	JAN	FEB	MAR	APR
West Yellowstone SNOTEL Site							
Average SWE per Month, 2004	0.03	3.5	10.9	20.6	25.8	28.7	5.5
Average SWE per Month, 1981-2003	0.3	3.1	10.0	16.6	22.6	27.7	21.7
2004 Percent of Average (1981-2003)	9	113	109	124	114	104	25
Maximum SWE per Month, 2004	0.3	6.6	16.0	23.9	29.2	30.7	20.8
Cumulative SWE, 2004	0.8	106.9	443.0	1082.0	1829.1	2719.6	2885.4
Madison Plateau SNOTEL Site							
Average SWE per Month, 2004	0.1	7.6	21.2	41.0	50.8	61.6	59.0
Average SWE per Month, 1981-2003	1.6	8.4	21.3	33.2	43.9	55.3	60.8
2004 Percent of Average (1981-2003)	7	90	99	124	116	111	97
Maximum SWE per Month, 2004	2.0	12.5	32.5	47.0	57.9	63.5	63.5
Cumulative SWE, 2004	3.6	231.4	889.5	2159.5	3632.7	5542.3	7313.4
Canyon SNOTEL Site							
Average SWE per Month, 2004	0.2	3.4	11.1	19.4	25.2	28.5	21.3
Average SWE per Month, 1981-2003	0.7	4.4	11.3	18.4	24.7	31.1	32.6
2004 Percent of Average (1981-2003)	26	78	98	105	102	91	65
Maximum SWE per Month, 2003	2.8	6.4	18.0	23.6	28.2	34.5	27.4
Cumulative SWE, 2004	5.6	108.0	462.3	1083.3	1815.1	2725.9	3343.2
Northeast Entrance SNOTEL Site							
Average SWE per Month, 2004	0.03	1.9	6.5	11.1	15.0	15.5	1.2
Average SWE per Month, 1981-2003	0.2	2.8	8.3	14.2	19.5	24.1	21.3
2004 Percent of Average (1981-2003)	8	69	78	78	77	64	6
Maximum SWE per Month, 2004	0.3	3.8	9.1	14.0	16.3	18.0	8.9
Cumulative SWE, 2004	0.5	57.7	258.1	601.5	1036.1	1516.1	1551.7

Table 2. Summary of observed wildlife groups and interactions with motorized winter use vehicles by kilometers (km) surveyed for each road segment during winter 2004, Yellowstone National Park, Wyoming.

Road Segment	**Total Kilometers Surveyed**	**Wildlife Groups Observed**	**Groups Observed per Kilometer Surveyed**	**Interactions Observed**	**Interactions Observed per Kilometer Surveyed**
Madison to West Yellowstone (23 km)	1415	1118	.79	887	.63
Madison to Old Faithful (26 km)	1569	1350	.86	981	.63
Mammoth to Norris (34 km)	710	145	.20	97	.14
Norris to Madison (23 km)	578	199	.34	127	.22
Mammoth to the Lamar Valley (60 km)	2354	942	.40	742	.32
West Thumb to South Entrance	256	9	.04	3	.01
Fishing Bridge to West Thumb (34 km)	1798	106	.06	31	.02
Canyon Village to Lake Butte (40 km)	2073	1055	1.96	294	.14
West Thumb to Old Faithful	636	16	.03	12	.02

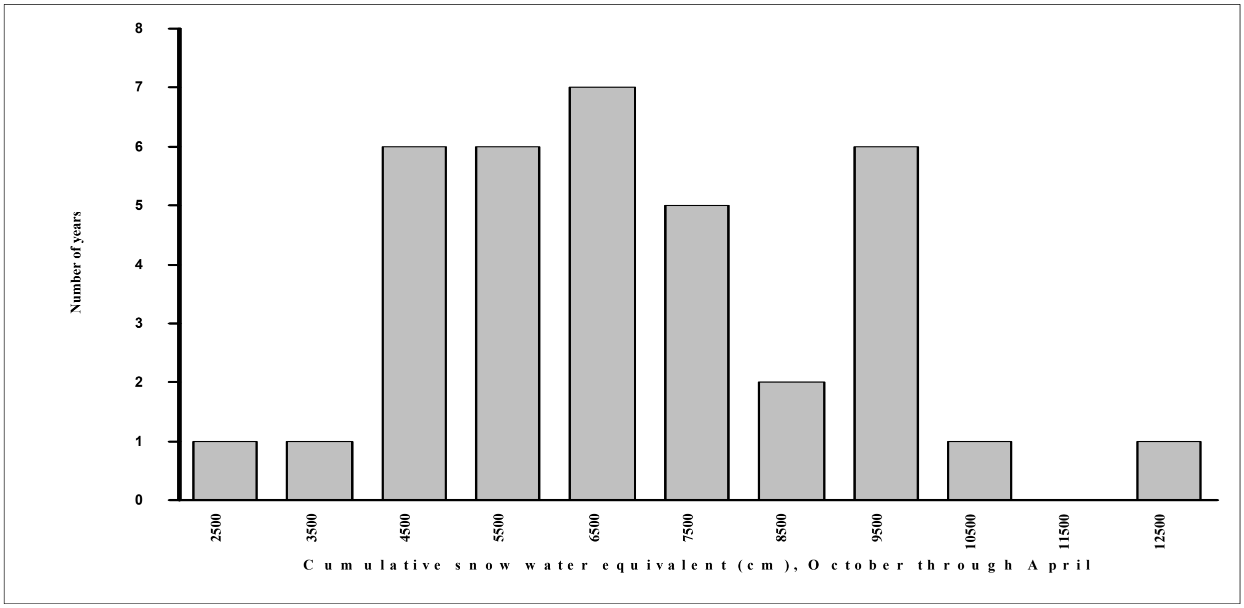


Figure 1. Frequency distribution of the number of winters during 1968-2003 with various cumulative snow water equivalent totals. Daily snow water equivalents were measured at the Madison Plateau SNOTEL site in Montana and summed over days during October 1st through April 30th to obtain the cumulative total per winter. For example, the category of snow water equivalent equal to 4,500 centimeters indicates that six winters had cumulative snow water equivalent totals between 4,000 and 4,999 centimeters.

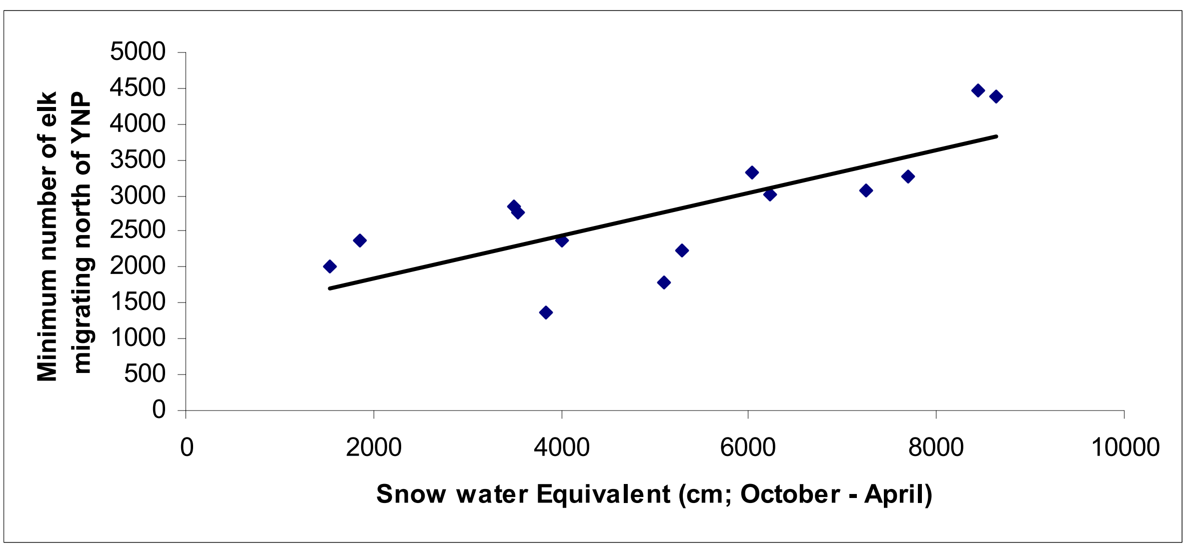


Figure 2. Relationship between cumulative snow water equivalent (cm) during October through April measured at the Northeast Entrance SNOTEL site and migration of northern Yellowstone elk out of Yellowstone National Park during 1989-2002.

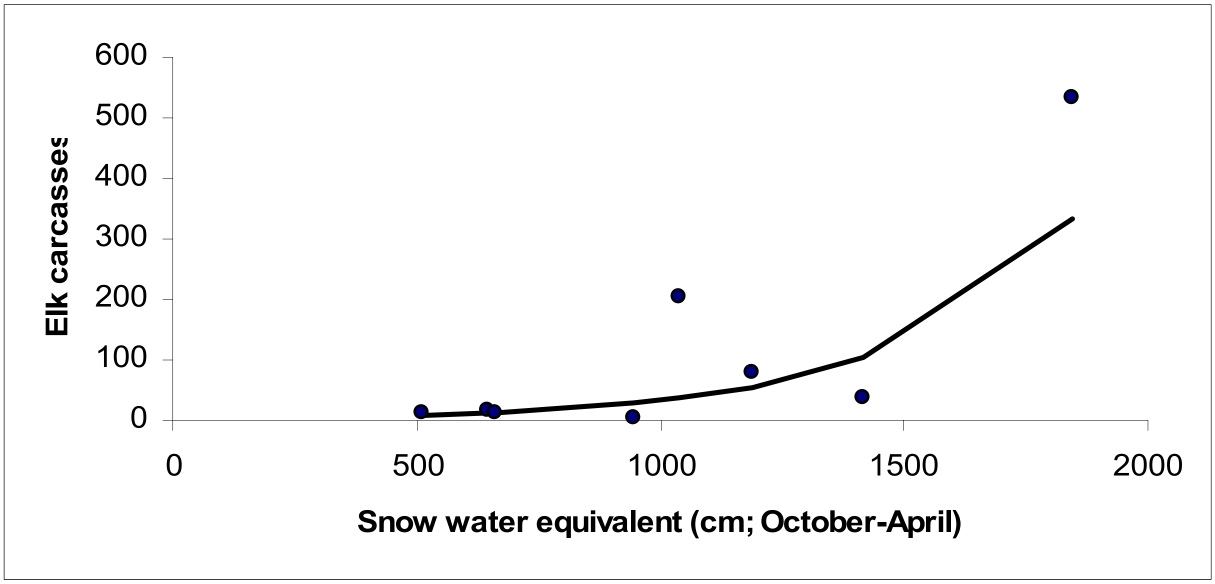


Figure 3. Relationship between cumulative snow water equivalent (cm) during October through April estimated at the Tower CLIM site and the number of carcasses detected during spring helicopter surveys of the Gardiner basin in 1989-1997 (i.e., prior to wolf recovery in this area).

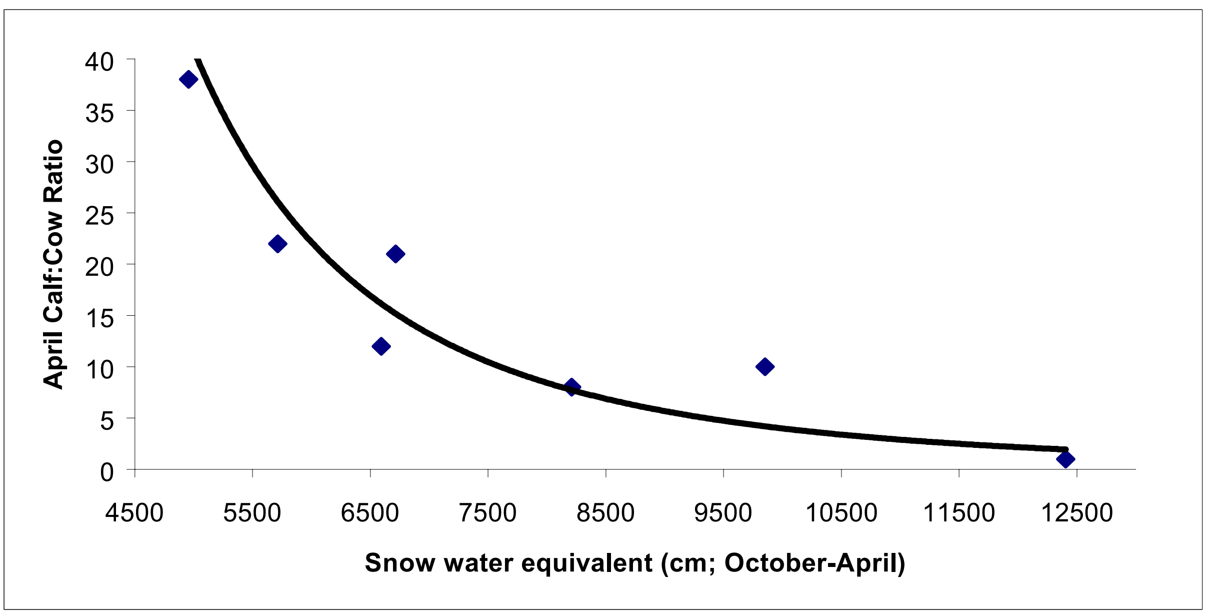


Figure 4. Relationship between cumulative snow water equivalent (cm) during October through April measured at the Madison Plateau SNOTEL site and an index of winter survival for central Yellowstone elk calves during 1992-1998 (i.e., prior to wolf re-establishment in this area).

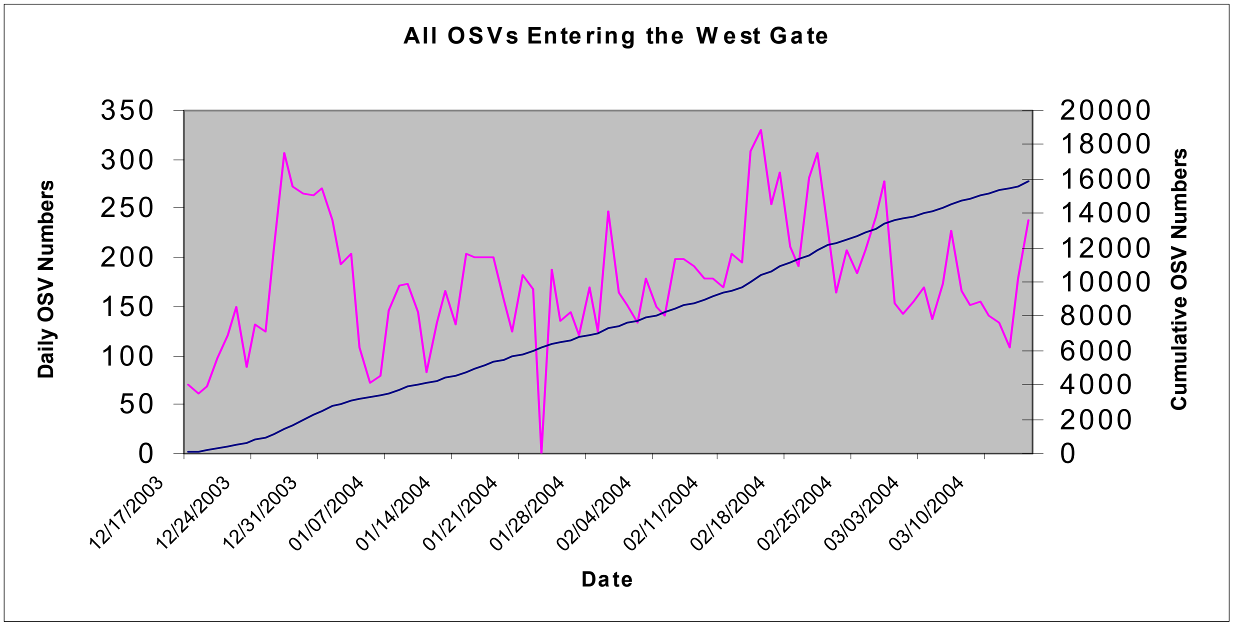


Figure 5. Daily and cumulative numbers of total over-the-snow vehicles (OSVs; i.e., snow coaches and commercially guided snowmobiles) entering the West Entrance Station of Yellowstone National Park during winter 2004.

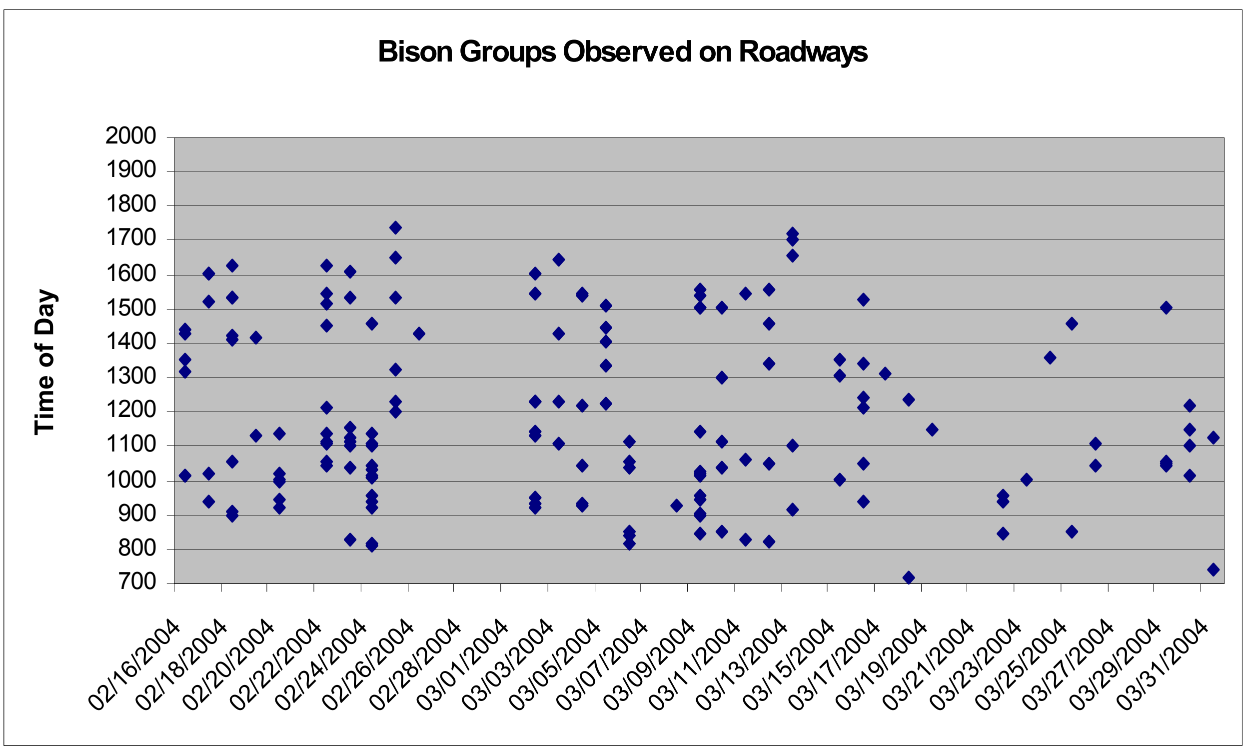


Figure 6. Timing of bison use of groomed roads during daylight survey hours, winter 2004, Yellowstone National Park, Wyoming.

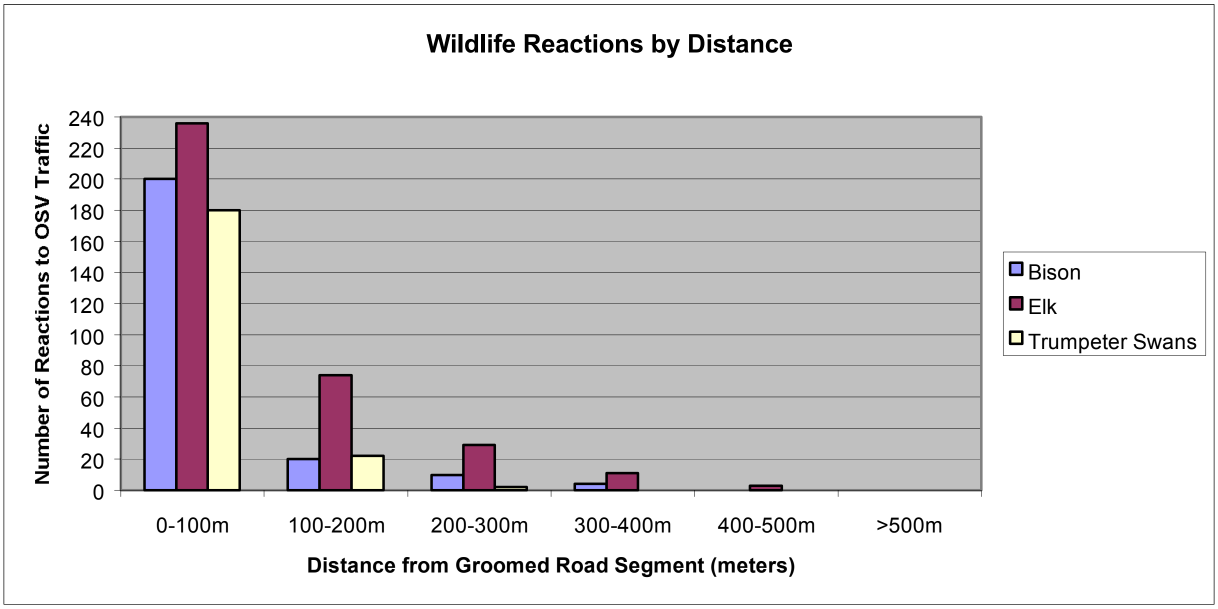


Figure 7. The number of visible reactions (i.e., look-resume, travel, alarm-attention, flight, or defense) displayed by groups of bison, elk, or swans near groomed road segments in Yellowstone National Park during winter 2004.

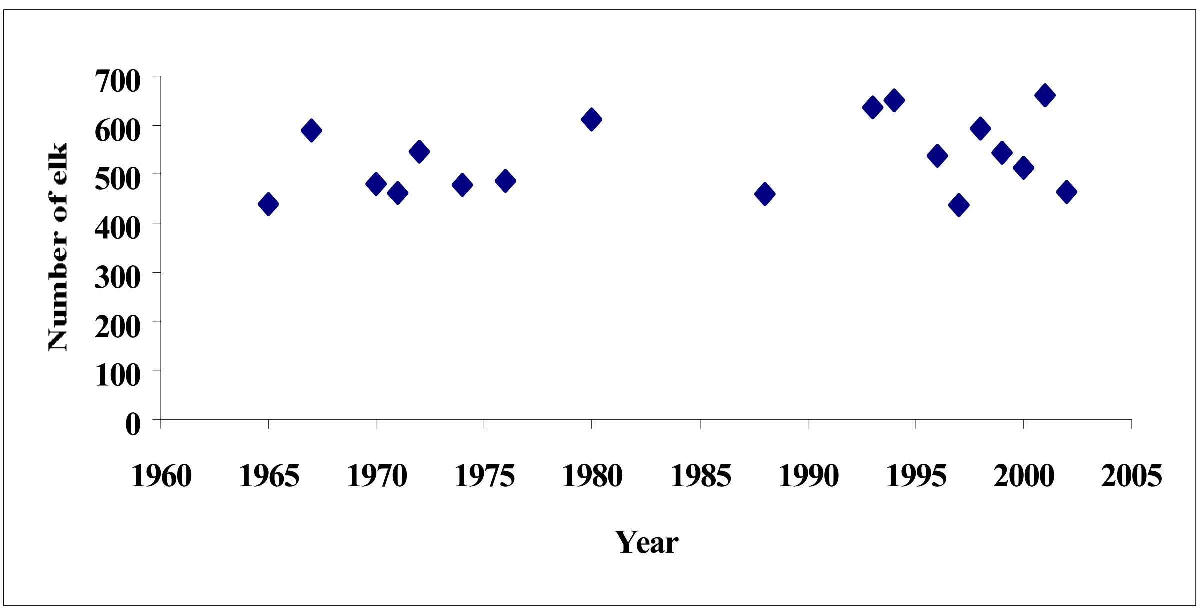


Figure 8. Estimates of abundance for central Yellowstone elk during 1965-2003, Yellowstone National Park, Wyoming.

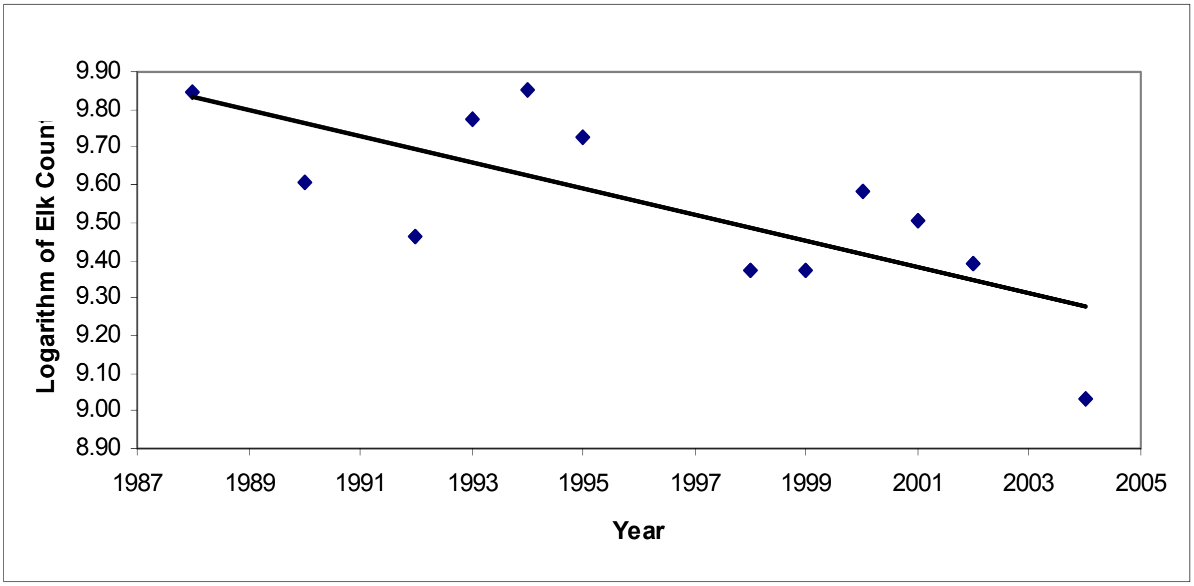


Figure 9. Trend of logarithm-transformed population counts of northern Yellowstone elk during 1988 to 2004.

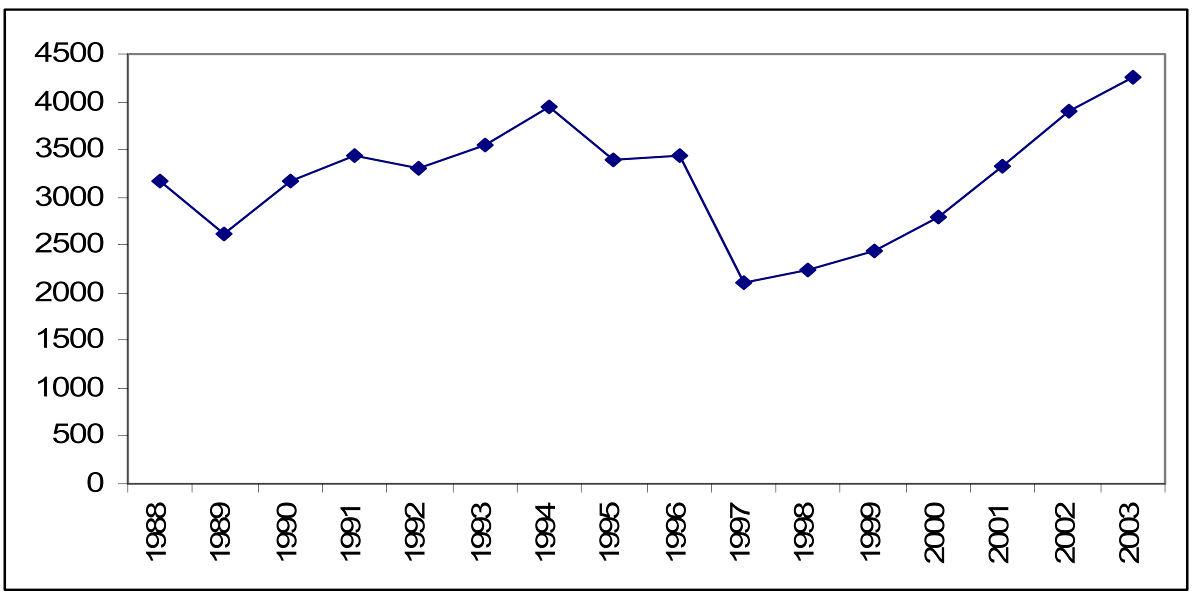
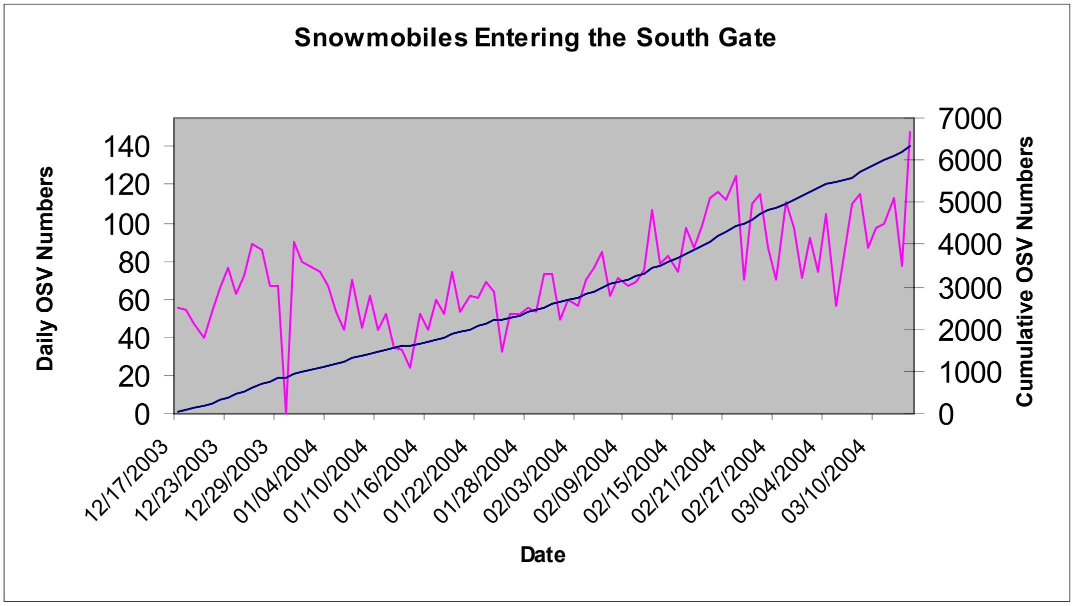
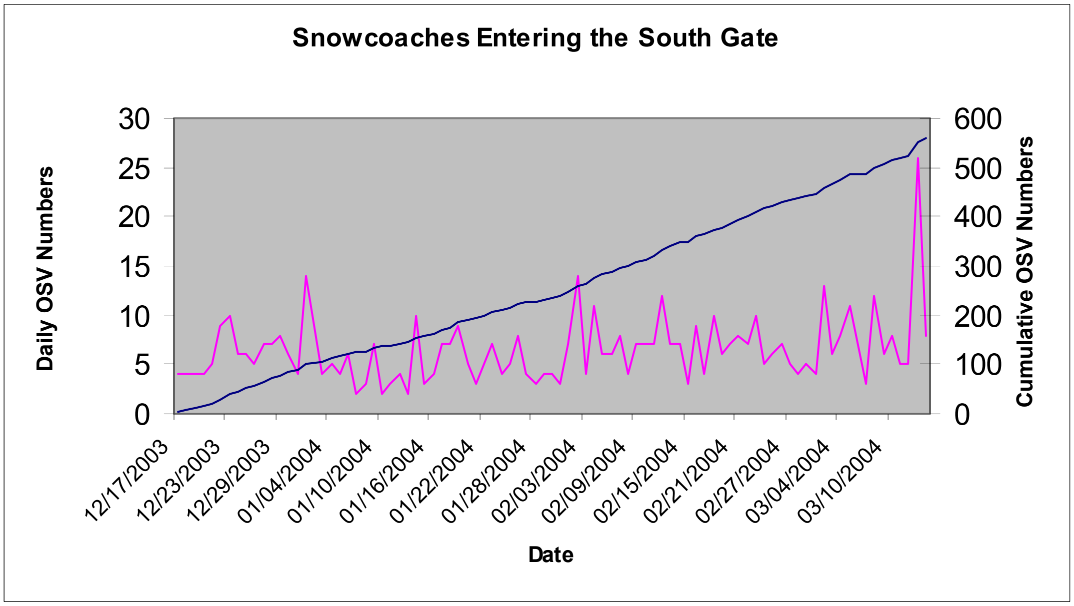


Figure 10. Trend in counts of Yellowstone bison during 1988-2003, Yellowstone National Park, Wyoming.

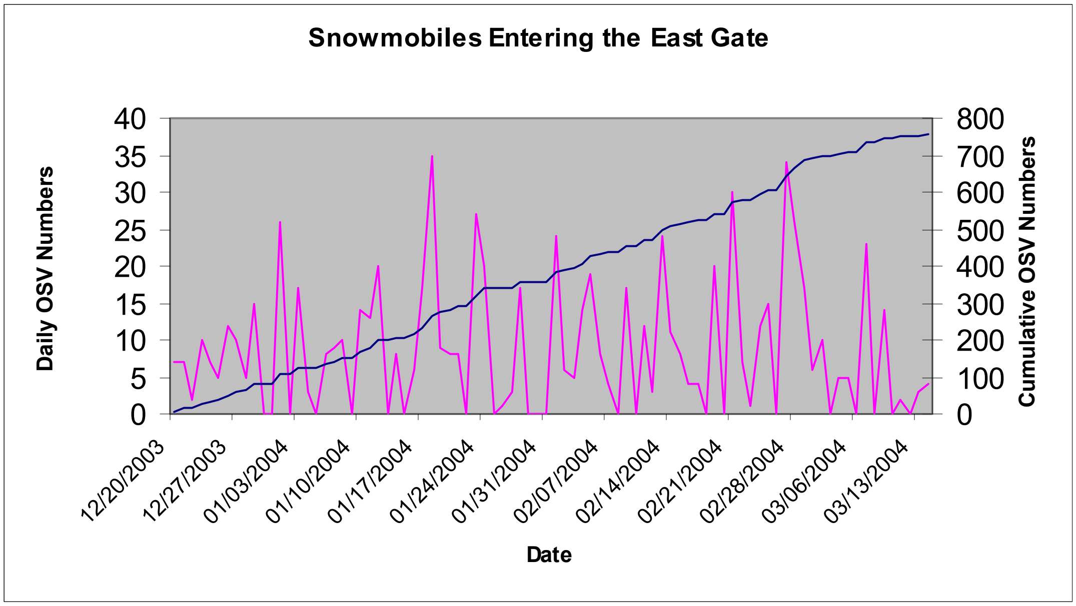
Appendix A: Daily and cumulative numbers of commercially guided snowmobiles, snow coaches, and combined (coach + snowmobile) over-the-snow vehicles (OSVs) entering various entrance stations of Yellowstone National Park during winter 2004. Daily totals are displayed on the left axis, while the winter's cumulative total is displayed on the right axis. Note that the scales of the Y axes vary among figures.

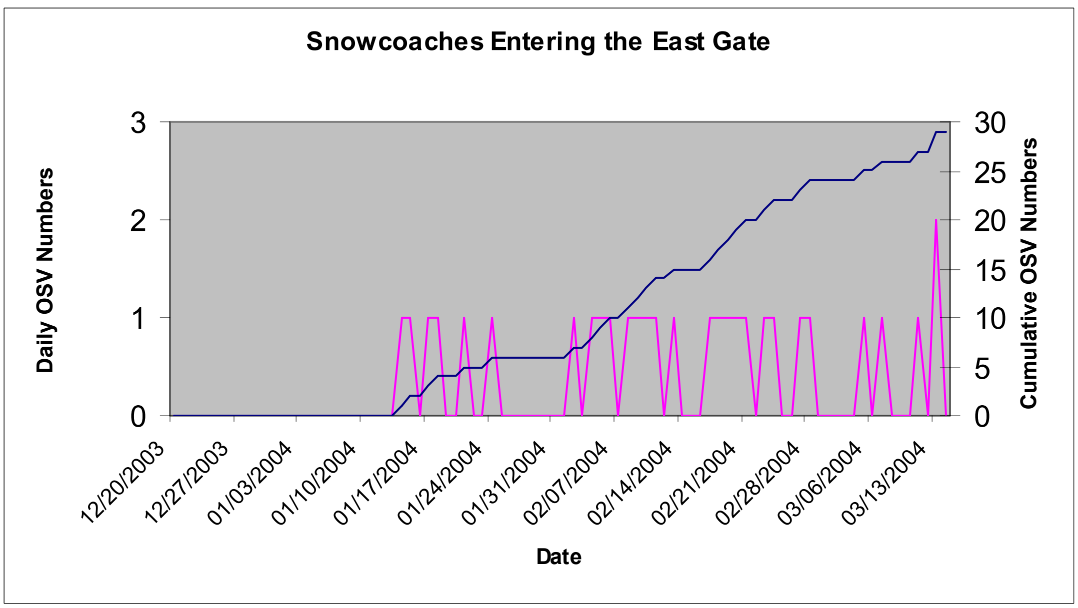
South Entrance Station



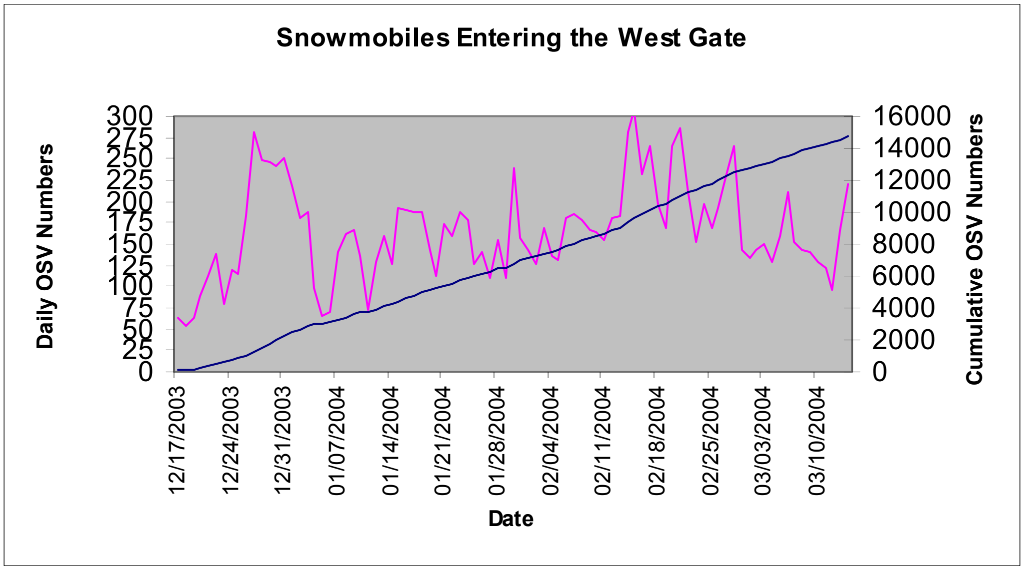


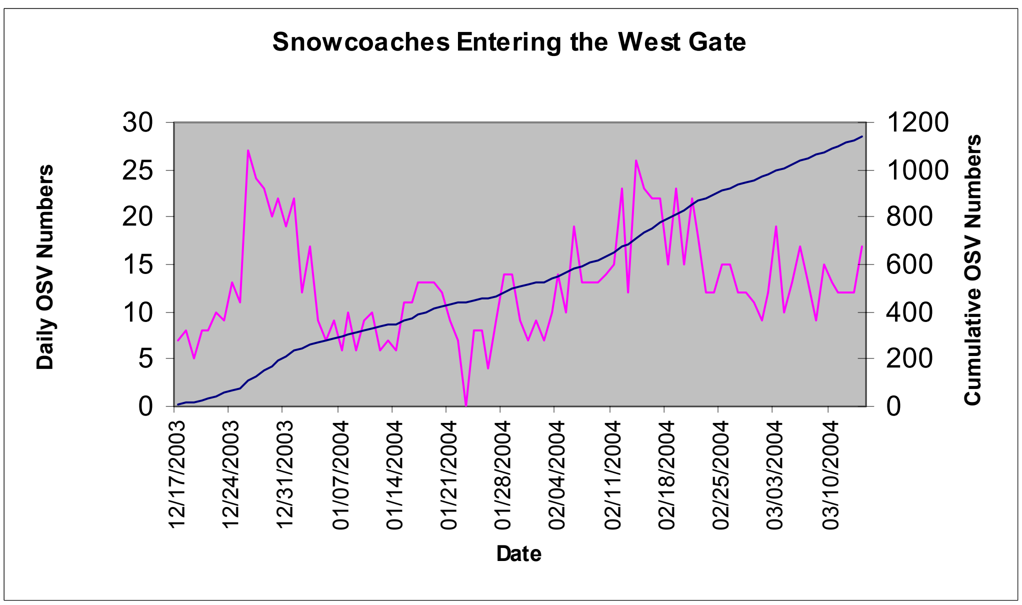
East Entrance Station





West Entrance Station





Appendix B: Budget for monitoring the potential effects of motorized use on wildlife during winter 2004, Yellowstone National Park, Wyoming.

Expenditures	Unit Cost	Total Cost	Organization
Personnel Services			
Temp NTE 1039 hr GS-7 Biotech	$1,313/PP @ 12PP (PP26-PP11) @ 1 person	$17,000	YCR
Temp NTE 1039 hr GS-5 Biotech	$1,060/PP @ 8PP (PP26-PP7) @ 5 persons	$46,000	80% CRO / 20% YCR
Volunteer	$150/PP @ 10PP (PP26-PP9) @ 1 person	$ 2,000	YCR
Volunteer housing	$100/PP @ 10PP (PP26-PP9) @ 1 person	$ 1,500	YCR
Premium	OT and differential	$ 1,500	70% CRO / 30% YCR
Clerical support		$ 4,500	70% CRO / 30% YCR
Supplies and Equipment			
RACAL radios, battery packs, and battery chargers	2 packages @ $2,500 each	$ 5,000	CRO
RACAL radios, battery packs, and battery chargers	2 packages @ $2,500 each	$ 5,000	YCR
Miscellaneous equipment and repairs		$ 5,000	YCR
Contractors and Cooperators			
Biostatistician: data analyses and sampling design	Dr. John Borkowski, Montana State University	$15,000	YCR
Fecal collection for future glucocorticoid assays	Dr. Robert Garrott, Montana State University	$ 4,000	YCR
Fecal glucocorticoid assays	Dr. Scott Creel, Montana State University	$ 4,000	YCR
Wildlife Distribution Survey Flights	Nine flights@ 6 hours/flight@$150/hour	$ 9,000	YCR
Fuel for elk and bison monitoring	Dr. Robert Garrott, Montana State University, 1,400 gallons @ $1.40/gallon	$ 2,000	YCR
Per Diem (travel, lodging)	Dr. John Borkowski, Montana State University, periodic visits to YNP for consultation, etc.	$ 1,000	YCR
Awards		$ 2,500	50% CRO/ 50% YCR
Total		**$125,000**	

Appendix C. Summaries of observed wildlife groups and interactions by road segment and survey crew during December 12, 2003, through April 1, 2004, Yellowstone National Park, Wyoming.

Summary of observed wildlife groups and interactions with motorized winter use by species and road segment. 'OSV' indicates the number of interactions with over-snow vehicles, 'WV' indicates interactions with wheeled vehicles on plowed roads, and P indicates interactions with non-motorized humans (skiers, bikers, etc). Following the route name is the number of times the route was surveyed.

Road Segment	Species	Groups Observed	Interactions
Madison to Old Faithful (57)	Bald Eagle	78	43 (41 OSV and 2 WV)
	Bison	833	604 (547 OSV, 47 WV, 10P)
	Coyote	14	10 (8 OSV and 2 WV)
	Elk	319	260 (234 OSV, 22 WV, 4P)
	Golden Eagle	2	0
	Great Blue Heron	3	0
	Muskrat	1	0
	Red-tailed Hawk	1	0
	Rough-legged Hawk	4	0
	Short-tailed Weasel	1	0
	Swans	92	62 (61 OSV and 1 WV)

Road Segment	Species	Groups Observed	Interactions
Madison to West Yellowstone (66)	Bald Eagle	115	72 (67 OSV, 4 WV, 1P)
	Bison	204	162 (139 OSV, 20 WV, 3P)
	Coyote	14	12 OSV
	Elk	448	373 (334 OSV, 29 WV, 10 P)
	Golden Eagle	4	0
	Great Blue Heron	8	0
	Muskrat	2	0
	Red-tailed Hawk	2	0
	Rough-legged Hawk	1	0

	Swans	320	268 (263 OSV, 2 WV, 3P)

Road Segment	**Species**	**Groups Observed**	**Interactions**
Norris to Madison (25)	Bald Eagle	12	6 (4 OSV and 2 WV)
	Bison	137	91 (84 OSV and 7 WV)
	Coyote	2	2
	Elk	43	27 (24 OSV, 2 WV, 1P)
	Swans	5	1

Road Segment	**Species**	**Groups Observed**	**Interactions**
Norris to Mammoth (26)	Bald Eagle	12	7 (6 OSV and 1 WV)
	Bison	107	70 (67 OSV, 2 WV, 1P)
	Coyote	4	1
	Elk	11	10
	Golden Eagle	1	1
	Swans	10	8

Road Segment	**Species**	**Groups Observed**	**Interactions**
Mammoth to Lamar Valley (38)	Bald Eagle	11	7
	Bighorn Sheep	11	9
	Bison	548	464
	Coyote	89	70
	Elk	256	169
	Golden Eagle	6	3
	Mule Deer	2	1
	Pronghorn	4	4
	Red Fox	2	1
	River Otter	1	1
	Swans	3	3
	Wolf	13	11

Road Segment	**Species**	**Groups Observed**	**Interactions**
Canyon to Lake Butte (98)	Bald Eagle	38	5
	Bison	673	186
	Coyote	77	36
	Elk	2	0
	Grizzly Bear	1	1 WV

Summary of observed wildlife groups and interactions with motorized winter use by road segment:

Road Segment	Observations	% of Total Observations	Interactions	% of Total Interactions
Madison to West Yellowstone (23 km)	1118	23	887	28
Madison to Old Faithful (26 km)	1350	27	981	31
Mammoth to Norris (34 km)	145	3	97	3
Norris to Madison (23 km)	199	4	127	4
Mammoth to the Lamar Valley (60 km)	942	19	742	23
West Thumb to South Entrance (35 km)	9	.2	3	.1
Fishing Bridge to West Thumb (34 km)	106	2	31	1
Canyon Village to Lake Butte (40 km)	1055	21	294	9
West Thumb to Old Faithful (27 km)	16	.3	12	.4

Summary of observed wildlife groups and interactions with motorized winter use by survey crew:

Area	Observations	% of Total Observations	Interactions	% of Total Interactions
Madison	2468	50	1868	59
Mammoth	1286	26	966	30
Lake	1186	24	340	11

Summary of the percentage of observed wildlife groups for which interactions with motorized winter use were documented by each survey crew:

Area	Observations	% of Observations that Documented Responses
Madison	2468	76
Mammoth	1286	75
Lake	1186	29

Appendix D. Comparison of human behavior during interactions with wildlife (i.e., bison, elk, trumpeter swans) during December 12, 2003, through April 1, 2004, Yellowstone National Park, Wyoming. The human behavior is compared among commercially guided groups of snowmobiles and snow coaches, administrative groups of snowmobiles and snow coaches (i.e., park and concessionaire staff), and wheeled vehicles.

Snow Coach Users Responses to Wildlife in the Madison District (Madison to Old Faithful and Madison to West Yellowstone)

Elk

Human Behavior	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	76	60.3	9	88.9
Stop	31	24.6	0	0.0
Dismount	9	7.1	0	0.0
Approach	4	3.2	0	0.0
Impede-Hasten	6	4.8	1	11.1

Bison

Human Behavior	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	124	63.9	8	88.9
Stop	45	23.2	0	0.0
Dismount	7	3.6	0	0.0
Approach	3	1.5	0	0.0
Impede-Hasten	15	7.7	1	11.1

Swans

Human Behavior	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	42	46.7	5	100.0
Stop	35	38.9	0	0.0
Dismount	4	4.4	0	0.0
Approach	9	10.0	0	0.0

Snow Coach Users Response to Wildlife in the Lake District (i.e., Canyon to Lake Butte, Fishing Bridge to West Thumb, West Thumb to South Entrance, and West Thumb to Old Faithful)

Elk

Human Behavior	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	1	100.0	1	100.0

Bison

Human Behavior	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	11	64.7	3	50.0
Stop	3	17.6	2	33.3
Dismount	2	11.8	0	0.0
Approach	0	0.0	0	0.0
Impede-Hasten	1	5.9	1	16.7

Swans

Human Behavior	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	4	80.0	0	0.0
Approach	1	20.0		

Snow Coach Users Response to Wildlife in the Mammoth District (i.e., Mammoth to Norris and Norris to Madison)

Elk

Human Behavior	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	3	50.0	2	100.0
Stop	3	50.0		

Bison

Human Behavior	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	18	58.1	10	90.9
Stop	9	29.0	1	9.1
Dismount	3	9.7	0	0.0
Approach	1	3.2	0	0.0

Swans

Human Behavior	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	2	100.0	0	0.0

Snowmobile Users Response to Wildlife in the Madison District (i.e., Madison to West Yellowstone and Madison to Old Faithful)

Elk

Human Behavior	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	161	77.0	92	41.6
Stop	14	6.7	91	41.2
Dismount	12	5.7	12	5.4
Approach	16	7.7	1	0.5
Impede-Hasten	6	2.9	25	11.3

Bison

Human Behavior	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	202	70.9	127	64.8
Stop	24	8.4	49	25.0
Dismount	15	5.3	4	2.0
Approach	18	6.3	1	0.5
Impede-Hasten	26	9.1	15	7.7

Swans

Human Behavior	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	91	75.2	52	48.1
Stop	11	9.1	46	42.6
Dismount	9	7.4	5	4.6
Approach	9	7.4	3	2.8
Impede-Hasten	1	0.8	2	1.9

Snowmobile Users Response to Wildlife in the Lake District (i.e., Canyon to Lake Butte, Fishing Bridge to West Thumb, West Thumb to South Entrance, and West Thumb to Old Faithful)

Elk

Human Behavior	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	0	0.0	2	50.0
Stop	0	0.0	2	50.0

Bison

Human Behavior	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	4	66.7	36	29.0
Stop	0	0.0	77	62.1
Dismount	2	33.3	1	0.8
Approach	0	0.0	1	0.8
Impede-Hasten	0	0.0	9	7.3

Swans

Human Behavior	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	2	50.0	11	36.7
Stop	0	0.0	19	63.3
Dismount	2	50.0	0	0.0

Snowmobile Users Response to Wildlife in the Mammoth District (i.e., Mammoth to Norris and Norris to Madison)

Elk

Human Behavior	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	8	61.5	6	42.9
Stop	2	15.4	7	50
Dismount	3	23.1	1	7.1

Bison

Human Behavior	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	27	50.9	36	70.6
Stop	13	24.5	7	13.7
Dismount	11	20.8	6	5.9
Approach	1	1.9	2	3.9
Impede-Hasten	1	1.9	3	5.9

Swans

Human Behavior	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	1	25.0	2	66.7
Stop	2	50.0	0	0.0
Dismount	1	25.0	0	0.0
Approach	0	0.0	1	33.3

Wheeled Vehicle Areas (i.e., plowed road from Mammoth to Pebble Creek and spring administrative use on other road segments was included in this dataset)

Elk

Human Behavior	Commercially Guided Groups		Unguided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion	No. Events	Proportion
None	3	75.0	89	76.0	60	59.4
Stop			17	14.5	35	34.7
Dismount	1	25.0	8	6.8	3	3.0
Approach			3	2.6	1	1.0
Impede-Hasten					2	2.0

Bison

Human Behavior	Commercially Guided Groups		Unguided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion	No. Events	Proportion
None	7	46.6	305	76.6	104	80.6
Stop	4	26.7	60	15.1	5	3.9
Dismount	4	26.7	21	5.3	19	14.7
Approach			10	2.5	1	.8
Impede-Hasten			2	.5		

Swans

Human Behavior	Commercially Guided Groups		Unguided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion	No. Events	Proportion
None	1	100.0	2	66.7	8	88.9
Stop					1	11.1
Dismount			1	33.3		

Appendix E. Comparison of wildlife (bison, elk, and swans) responses during interactions with commercially guided groups of snowmobiles and snow coaches, administrative groups of snowmobiles and snow coaches (i.e., park and concessionaire staff), and wheeled vehicles during December 12, 2003 through April 1, 2004, Yellowstone National Park, Wyoming.

Wildlife Responses to Snowmobile Users in the Madison District (i.e., Madison to Old Faithful and Madison to West Yellowstone)

Elk

Wildlife Response	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	102	48.8	68	30.8
Look-Resume	53	25.4	49	22.2
Travel	6	2.9	24	10.9
Alarm-Attention	40	19.1	72	32.6
Flight	8	3.8	8	3.6

Bison

Wildlife Response	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	219	76.8	156	79.6
Look-Resume	20	7.0	4	2.0
Travel	24	8.4	19	9.7
Alarm-Attention	14	4.9	11	5.6
Flight	7	2.5	6	3.1
Defense	1	0.4	0	0.0

Swans

Wildlife Response	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	55	45.5	44	40.7
Look-Resume	27	22.3	17	15.7
Travel	12	9.9	33	30.6
Alarm-Attention	25	20.7	13	12.0
Flight	2	1.7	1	0.9

Wildlife Responses to Snowmobile Users in the Lake District (i.e., Canyon to Lake Butte, Fishing Bridge to West Thumb, West Thumb to South Entrance, and West Thumb to Old Faithful)

Elk

Wildlife Response	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	0	0	2	50.0
Look-Resume	0	0	2	50.0

Bison

Wildlife Response	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	6	100.0	75	60.5
Look-Resume	0	0.0	33	26.6
Travel	0	0.0	5	4.0
Alarm-Attention	0	0.0	5	4.0
Flight	0	0.0	5	4.0
Defense	0	0.0	1	0.8

Swans

Wildlife Response	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	13	87.0	18	58.1
Look-Resume	2	13.0	10	32.2
Travel	0	0.0	1	3.2
Alarm-Attention	0	0.0	1	3.2
Flight	0	0.0	1	3.2

Wildlife Responses to Snowmobile Users in the Mammoth District (i.e., Mammoth to Norris and Norris to Madison)

Elk

Wildlife Response	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	11	84.6	7	50.0
Look-Resume	0	0.0	6	42.9
Travel	2	15.4	0	0.0
Alarm-Attention	0	0.0	1	7.1
Flight	0	0.0	0	0.0

Bison

Wildlife Response	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	51	96.2	44	86.3
Look-Resume	0	0.0	3	5.9
Travel	1	1.9	3	5.9
Alarm-Attention	0	0.0	1	2.0
Flight	1	1.9	0	0.0

Swans

Wildlife Response	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	3	75.0	2	66.7
Look-Resume	1	25.0	0	0.0
Travel	0	0	1	33.3

Wildlife Responses to Snow Coach Users in the Madison District (i.e., Madison to Old Faithful and Madison to West Yellowstone)

Elk

Wildlife Response	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	64	50.8	1	10.0
Look-Resume	27	21.4	6	60.0
Travel	7	5.6	1	10.0
Alarm-Attention	23	18.3	2	20.0
Flight	4	3.2	0	0.0
Defense	1	0.8	0	0.0

Bison

Wildlife Response	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	149	76.8	6	66.7
Look-Resume	15	7.7	1	11.1
Travel	16	8.2	1	11.1
Alarm-Attention	9	4.6	0	0.0
Flight	5	2.6	1	11.1

Swans

Wildlife Response	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	38	42.2	2	40.0
Look-Resume	22	24.4	1	20.0
Travel	10	11.1	0	0.0
Alarm-Attention	19	21.1	2	40.0
Flight	1	1.1	0	0.0

Wildlife Responses to Snow Coach Users in the Lake District (i.e., Canyon to Lake Butte, Fishing Bridge to West Thumb, West Thumb to South Entrance, and West Thumb to Old Faithful)

Elk

Wildlife Response	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	1	100.0	1	100.0

Bison

Wildlife Response	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	14	82.4	5	83.3
Look-Resume	2	11.8	1	16.7
Travel	1	5.9	0	0.0

Swans

Wildlife Response	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	4	100.0	0	0.0

Wildlife Responses to Snow Coach Users in the Mammoth District (i.e., Mammoth to Norris and Norris to Madison)

Elk

Wildlife Response	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	7	4.5	1	50.0
Look-Resume	1	0.6	1	50.0

Bison

Wildlife Response	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	28	18.1	11	100.0
Look-Resume	0	0.0	0	0.0
Travel	2	1.3	0	0.0
Alarm-Attention	1	0.6	0	0.0

Swans

Wildlife Response	Commercially Guided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion
None	2	100.0	0	0.0

Wildlife Responses to Wheeled Vehicles (i.e., plowed road from Mammoth to Pebble Creek and spring administrative use on other road segments was included in this dataset).

Elk

Wildlife Response	Commercially Guided Groups		Unguided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion	No. Events	Proportion
None	4	100	111	94.9	75	63.6
Look-Resume	0	0.0	3	2.6	24	20.3
Travel	0	0.0	2	1.7	6	5.1
Alarm-Attention	0	0.0	1	0.9	9	7.6
Flight	0	0.0	0	0.0	4	3.4

Bison

Wildlife Response	Commercially Guided Groups		Unguided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion	No. Events	Proportion
None	14	93.3	384	96.5	122	89.1
Look-Resume	0	0.0	6	1.5	5	3.6
Travel	0	0.0	6	1.5	5	3.6
Alarm-Attention	1	6.7	2	0.5	2	1.5
Flight	0	0.0	0	0.0	3	2.2

Swans

Wildlife Response	Commercially Guided Groups		Unguided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion	No. Events	Proportion
None	0	0.0	2	66.7	9	100.0
Look-Resume	0	0.0	1	33.3	0	0.0
Alarm-Attention	1	100.0	0	0.0	0	0.0