The National Park Service

WILDLIFE RESPONSES TO MOTORIZED WINTER RECREATION IN YELLOWSTONE NATIONAL PARK

2003 ANNUAL REPORT
(December 16, 2002 through April 18, 2003)

Collaborative Effort by the:

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

Report prepared by:

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

in collaboration with

Dan Reinhart, Craig McClure, Patrick Perotti
Resource Management & Visitor Protection
&
Terry McEneaney, Glenn Plumb, Doug Smith, Rick Wallen
Yellowstone Center for Resources

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This report is intended to provide a summary of baseline data collected during winter 2003 for comparison to similar data collected during previous and future winters. Statistical analyses of the data are ongoing. Thus, information contained in this report is preliminary and should not be published, reproduced, or used for other purposes without written permission from the authors and/or collaborators.

Executive Summary

Staff from the Yellowstone Center for Resources and Resource Management & Visitor Protection Office monitored wildlife responses to motorized winter recreation during December 16, 2002 through April 18, 2003. The purpose of this monitoring was to collect baseline information on existing conditions for comparison to data collected after the implementation of changes in winter use management during winter 2004. Such comparisons will enable us to evaluate the effectiveness of changes in management at attaining desired conditions.

The winter of 2003 was relatively mild in terms of snow pack and temperatures. As a result, visitor over-the-snow vehicle traffic was relatively low in comparison to previous winters. We used snowmobiles and wheeled vehicles to conduct repeated surveys of wildlife responses to motorized winter use vehicles and human activities along eight groomed or plowed road segments in areas of both low and high intensity human and wildlife use. 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 efforts on monitoring 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 recreation activities during winter.

Overall, the responses of wildlife to over-the-snow vehicles and associated humans was typically minor, with 61% of the observed responses by groups of bison, elk, and swans categorized as no apparent response, 23% look/resume, 5% attention/alarm, 8% travel, 2% flight, and 1% defense. Wildlife responses to motorized winter use were species dependent and the likelihood of observing an active response by bison and swans (but not for elk) increased as the numbers of snowmobiles in a group increased. Also, the likelihood of observing an active response by elk and swans (but not for bison) increased as the numbers of snow coaches in a group increased. The likelihood of a response by each species decreased as distance from the road increased.

Trends in the abundance of bison and elk populations since the onset of motorized winter use in Yellowstone National Park provide no evidence of population-level effects to ungulates from motorized winter use, with the abundance of bison and elk either increasing or remaining 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.

Based on monitoring results during winter 2003, 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; and 3) reduce the number of stops to observe wildlife and human activities away from vehicles during these stops. We are currently analyzing data collected during 1999-2003 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 important disturbance factors. These analyses should help us refine our recommendations for adaptive management of motorized winter use to minimize the frequency of possible disturbances to wildlife.

The following paragraphs contain additional information our monitoring efforts during winter 2003. For a more detailed presentation, we suggest that the reader review Chapter I (Introduction) and Chapter III (Results). Additional information regarding our methods and discussion of our findings is provided in Chapter II (Methods) and Chapter IV (Discussion). Recommendations for adaptive management and improving the monitoring protocol during future winters are presented in Chapter V (Recommendations).

Synopsis of Findings:
In general, average snow water equivalents (i.e., the amount of water in the snow) per month were lower than the overall monthly averages since 1981. For example, the cumulative snow water equivalent value of 4,999 centimeters at the Madison Plateau SNOTEL site during winter 2003 was lower than totals obtained during 28 of the past 36 winters at this site. Similarly, ambient temperatures during winter 2003 were relatively moderate for ungulates. Only one day had a minimum temperature below the approximate effective critical temperature for bison (i.e., -34°F), and <12% of total days were less than the approximate effective critical temperature for elk (i.e., 0°F).

The number of snowmobiles entering the West Entrance Station exceeded 550 machines, which is the daily snowmobile entry limit for the winters of 2004 and 2005, on only one day. The numbers of snowmobiles entering the South and East Entrance Stations during winter 2003 did not exceed the daily snowmobile entry limits for each station during the winters of 2004 and 2005 (i.e., South = 250 snowmobiles; East = 100 snowmobiles). The cumulative total of over-the-snow vehicles entering the West Entrance Station surpassed 7,500 vehicles on January 20th during winter 2003. In contrast, this threshold was reached on December 31st during the winters of 1999 and 2000.

During daylight hours, observers traveled until a wildlife group (i.e., ≥1 animal) was detected within 500 meters of the road. The observers remained in a position along the road to observe the group until ≥1 motorized winter vehicle (i.e., snowmobile, snow coach, wheeled vehicle) entered a zone within 500 meters of the group. The observers categorized the motorized vehicle/human activity and associated wildlife response during a single interaction (i.e., one group of vehicles and the response by the group of wildlife) and then continued the survey to locate the next group of wildlife along the road segment. The observers categorized the highest level of human activity (i.e., most potential for disturbance) and predominant response behavior of the majority of the animals in the group during interactions.

Winter use crews conducted 332 surveys of road segments, covering 11,182 kilometers. Observers recorded 4,269 groups of wildlife during these surveys, including 908 groups of elk, 2,294 groups of bison, 447 groups of swans, and 620 groups of other species (e.g., bald eagles, coyotes, wolves). Observers recorded human behaviors and the responses of wildlife to motorized winter vehicles during 3,020 interactions. No groups of wildlife were observed during 30 surveys of road segments.

The behavior of over-the-snow vehicles and associated humans in response to wildlife groups was typically 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, 5% stop/resume, 13% stop and observe for an extended period, 13% dismount over-the-snow vehicles, 8% approach wildlife, 1% impede and/or hasten wildlife, and 1% undetermined. Qualitative comparisons suggest that the behaviors of visitors were similar between low and high intensity use areas, and those associated with snowmobiles or snow coaches. There appeared to be a tendency for visitors in commercially guided snowmobile groups to approach wildlife more frequently than visitors in unguided snowmobile groups. This apparent difference may be misleading or nonexistent, however, owing to the relatively small sample of guided groups compared to unguided groups. Additional data from one or more winter seasons will be necessary to establish the reliability of these apparent differences.

Bison rarely responded to human activity along roads (22% of interactions), whereas elk and swans responded more often (≤58% of interactions). Behavioral responses of wildlife decreased as distance from motorized winter use corridors increased. The estimated odds of observing no response relative to either a look and resume or active response by bison, elk, and swans was significantly higher for each 100 meter increase in distance from the road. Also, mean distances of bison and elk groups from groomed road segments during winter 2003 did not indicate avoidance of the road as motorized use increased (as indicated by daily over-the-snow vehicle traffic entering the West Entrance Station). In combination with the relatively minor and infrequent responses by wildlife to over-the-snow vehicle traffic, these results suggest that wildlife habituated to motorized winter use.

Wildlife responses varied by species among commercially guided, unguided, and administrative groups during winter 2003. For example, the estimated odds of observing an active response relative to no response by <u>bison</u> were significantly higher for a commercially guided group than for an unguided group (under identical conditions). Conversely, the estimated odds of observing a look and resume response or an active response relative to no response by <u>elk</u> was significantly lower for a commercially guided group than for an unguided group. There were no statistically significant results among comparisons of <u>swan</u> responses to commercially guided, unguided, and administrative groups. We suspect that these somewhat inexplicable variations in associations among wildlife responses and guide status results from the relatively low sample of guided groups (<10% of cases) compared to unguided groups. Thus, these apparent differences must be viewed cautiously because they may be misleading or nonexistent. By collecting data over several winter seasons, we can reexamine this issue with an increased sample size to establish the reliability of these apparent differences.

Statistical analyses by Dr. Borkowski indicated that several other variables likely influence the odds of a response by bison, elk, and/or swans to motorized winter use. These variables include group size, habitat type, precipitation, visibility, wildlife activity (e.g., standing v. bedded), ambient temperature, interaction time, and daily numbers of motorized vehicles entering the south and west gates. For example, for each 10-animal increase in the size of a wildlife group during winter 2003, the estimated odds of observing no response relative to a look and resume response were significantly higher for both bison and elk. By collecting data over several winter seasons, the influence of these variables on wildlife responses can be reexamined with an increased sample size, thereby providing better inference.

Bison were observed on groomed roads during 159 of 1,668 observations of bison groups from December 27, 2002, through March 10, 2003. Thus, the vast majority of observed bison groups were using areas off the groomed roads. One hundred and twenty of the bison groups observed on groomed roads were traveling, whereas 36 groups were stationary and 3 groups were resting. The estimated odds of observing an active response relative to no response was 20 times greater when bison were on the road than when they were off the road. 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.

A total of 95 interaction events between ungulates and over-the-snow vehicles and associated humans were documented when animal groups were on the groomed roads, including 75 groups of snowmobiles and 20 groups of snow coaches. Thirteen percent of these snowmobile groups impeded or hastened wildlife movement. Twenty-five percent of these snow coach groups impeded or hastened wildlife movement. Wildlife were observed on the plowed road from Mammoth to the Northeast Entrance on 35 occasions during our surveys, including 14 bison groups, 16 coyote groups, and 5 elk groups. Wildlife were not trapped by, or forced to jump over, snow berms along the sides of the road during any of these observations.

Counts of trumpeter swans on the north and west shores of Yellowstone Lake and along the Yellowstone River peaked in late November at 496 swans, and decreased relatively consistently through late February as open water sections of the Yellowstone River diminished. Conversely, counts of trumpeter swans along the Madison and Firehole Rivers increased during late December, peaked at 47 swans in mid-January, and remained relatively high through early February. As the winter progressed, and open water areas in the park diminished, the proportion of the swan population counted within Yellowstone National Park decreased compared to areas outside the park. Thus, relatively fewer swans were exposed to motorized winter use in the park.

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. We collaborated with Dr. Robert Garrott, Montana State University, to collect fecal samples (105 total) at approximately 2-week intervals throughout the winter from 35 radiocollared adult female elk in the west-central portion of the park. We have contracted with Drs. Robert Garrott and 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. These analyses should be completed during 2004. The results of the analyses will be compared to similar samples collected during winters of 1999 and 2000 to evaluate the potential for chronic stress of ungulates in areas with relatively intensive motorized winter use.

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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 will 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) 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 percent 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, which will begin during the winter of 2004, staff from the Yellowstone Center for Resources and Resource Management & Visitor Protection Office collaborated to monitor wildlife responses to winter recreation during December 16, 2002 through April 18, 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.

Attachment A (Table 1, "Monitoring and adaptive management indicators, standards, and methods") of the ROD indicates that the management objectives regarding human use and its potential adverse effects on wildlife during winter in Yellowstone National Park are as follows:

- Ensure that garbage is unavailable to wildlife and minimize the habituation of wildlife to humans at warming huts and other facilities;
- Minimize human conflicts with ungulate (e.g., bison, elk) movements on plowed roads;
- Minimize vehicle-caused wildlife deaths or injuries;
- Minimize the avoidance, displacement, or harassment of wildlife from noise, vehicles, or other human activities;
- Minimize incidents of wildlife trapped by snow berms on plowed roads;
- Minimize the facilitation of ungulate use of groomed roads;
- Minimize displacement of carnivores (e.g., lynx, wolves) and adverse effects to their habitats;
- Minimize harassment or displacement of wildlife by non-motorized activities (e.g., skiing, snowshoeing); and

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[1] Throughout the report, winters are referred to by their ending year. Thus, the winter extending from November 2004 through April 2005 would be referred to as winter 2005.

- Minimize human-bear conflicts during pre- and post-denning periods.

This report summarizes results of efforts to monitor wildlife responses to winter recreation during December 16, 2002 through April 18, 2003. Dr. John Borkowski, a statistician at Montana State University, is currently analyzing data collected during 1999-2003 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. These analyses should also enable us to develop a rigorous long-term monitoring plan that evaluates if human presence or activities have a detrimental effect on wildlife populations in Yellowstone National Park following the implementation of proposed management changes in human use during the winter of 2004.

During winter 2003, we also collaborated with Dr. Robert Garrott, Montana State University, to collect fecal samples (105 total) at approximately 2-week intervals throughout the winter from 35 radiocollared adult female elk in the west-central portion of the park. We have contracted with Drs. Robert Garrott and 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. These analyses should be completed during 2004. The results of the analyses will be compared to similar samples collected during winters of 1999 and 2000 to evaluate the potential for chronic stress of ungulates in areas with relatively intensive motorized winter use.

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 2003, 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 and unguided groups of snowmobiles?

We did <u>not</u> collect 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):

- Ensure that garbage is unavailable to wildlife and minimize the habituation of wildlife to humans at warming huts and other facilities;
- Minimize displacement of carnivores (e.g., lynx, wolves) and adverse effects to their habitats;
- Minimize harassment or displacement of wildlife by non-motorized activities (e.g., skiing, snowshoeing); and
- Minimize human-bear conflicts during pre- and post-denning periods.

Rather, other park programs were implemented to address these objectives, including: 1) resource management activities on garbage management and wildlife habituation at warming huts and other facilities; 2) monitoring of the occurrence and distribution of lynx and other small carnivores; 3) monitoring of the demographics, distribution, and movements of wolves; 4) visitor education on the potential for displacement of wildlife by non-motorized users; 5) development of management guidelines to minimize possible adverse effects of non-motorized recreation to wintering wildlife during severe winters when conditions cause ungulates to concentrate in certain areas and increase their susceptibility to winterkill; and 6) bear management programs to minimize human-bear conflicts during pre- and post-denning periods.

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 a higher water content. Ungulates can tolerate higher levels of SWE early in the winter than later in the winter but, in general, tend to concentrate in areas with lower SWE 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. We used minimum temperature data from the Madison Plateau and Northeast Entrance 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 west-central and northern portions of the park, respectively (Farnes et al. 1999).

Motorized Use Data

In coordination with the Visitor Services Office, we analyzed daily visitation statistics for the 2002-2003 winter season. 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 over-the-snow vehicles that entered the park each day, and the proportions of those visitors that were in guided and unguided groups.

Human Behaviors and Wildlife Responses

To the extent feasible, the 2003 monitoring replicated the methodology and experimental design of Hardy (2001). 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). 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 (Jaffe et al. 2002, Kurz et al. 1998, 1999; Reinertson et al. 2000, 2002). A summary of studies regarding wildlife responses to motorized winter use in Yellowstone National Park during 1981 to 2002 is provided in 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 eight groomed or plowed road segments. These road segments were selected to provide a sample of areas with both low and high intensity human and wildlife use. Portions of these road segments that were only open to travel by snow coaches (i.e., Riverside Drive, Freight Road, Firehole Canyon Drive, Virginia Cascades, Dunraven Pass, North Rim 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	Lower Geyser Basin entrance	Midway Geyser Basin exit
3. Madison to Norris	Madison junction	Norris junction
4. Norris to Canyon Village	Norris junction	Canyon junction
(C) Virgina Cascades	Cascades entrance	Cascades exit
(C) Canyon to Dunraven	Canyon Village	Washburn Overlook
5. Canyon Village to Lake Butte	Canyon junction	Lake Butte (overlook entrance)
6. Fishing Bridge to West Thumb	Fishing Bridge	West Thumb
7. Norris to Mammoth	Norris junction	north end of Swan Lake flats
8. Mammoth to Lamar Valley	High Bridge	Round Prairie/Pebble Creek

Survey crews were based in Madison Junction, Canyon Village, and Mammoth Hot Springs. 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 Canyon crew sampled the Canyon Village to Lake Butte, Norris to Canyon, and West Thumb to Fishing Bridge road segments. The Canyon crew also surveyed Virginia Cascades and North Rim Drive, which are designated for snow coaches only. At the request of sub-district law enforcement, these snow coach-only routes were surveyed using a park Mat-Track vehicle.

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.

Surveys were only conducted during daylight hours for safety and efficiency reasons. Surveys were conducted by a pair of observers driving snowmobiles at $\leq$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., $\geq$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 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); 4) group size and composition (i.e., adult males, adult females, young-of-the-year); and 5) predominant activity of the group of animals (i.e., if two animals are bedded and three are feeding, then the predominant activity was listed as feeding). Activity was recorded as standing (i.e., stand, perch, feed), traveling (i.e., walk, swim, fly), or resting (i.e., bed, float). 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). Owing to the difficulties of observing precise behaviors at large distances with binoculars, activity was only classified for that portion of the group that was within approximately within 500 meters of the road.

If several assemblages of animals of the same species were located in the same vicinity, then the observers defined group membership based on how the assemblages of animals were distributed and moving in space. Following Clutton-Brock et al. (1982), factors that were considered included the relative distances between individuals, degree and form of interaction, similarity or synchrony of behavior, and similarity of orientation.

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. If any wildlife group member was within 500 meters of the road, then the observers remained in a position along the road to observe the group until $\geq$1 motorized vehicle (other than the observers' snowmobile or vehicle) entered a zone within 500 meters of the group. Motorized winter vehicles could enter the 500-meter zone from either direction along the road corridor. The observers categorized the motor vehicle/human activity and associated wildlife response during a single interaction (i.e., one group of vehicles and the response by the group of wildlife) and then continued the survey to locate the next group of wildlife along the road segment. If motorized vehicles and/or humans were already present within 500 meters of a group of wildlife when the observers detected the wildlife group, then the observers began recording the interaction upon detection. 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.

Prior to departing an area with a group of wildlife, the observers drove up to a position on the road approximately perpendicular to the group of wildlife and recorded the location using a global positioning system (GPS) unit. Observers also recorded the perpendicular distance and direction from the road to the nearest animal using a laser range finder. If the group was farther from the road than the maximum capability of the range finder, or the range finder could not focus on the animals, then the observers estimated the distance using 7.5 minute quad maps.

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 was guided by a commercial operator familiar with the park and its winter regulations; 5) duration that the motorized winter vehicles remained within the interaction zone; 6) if humans dismounted the motorized winter vehicles (e.g., stepped off snowmobile or stepped out of snow coach); 7) if humans approached the animal group and their distance from the road and nearest animal; 8) if humans initiated behaviors to attract the attention of wildlife (e.g., yelling, whistling, throwing objects); and 9) if wildlife movement was impeded, altered, or hastened by motorized winter vehicles. When documenting interactions between mixed guided and unguided motorized winter vehicle groups, observers recorded, where possible, differences in human behavior between guided and unguided groups.

The observers recorded the highest level of human activity (i.e., most potential for disturbance) during the interactions. Activities were categorized as follows:

- No visible reaction to wildlife;
- Stop for less than 15 seconds and then resume traveling;

- Stop for more than 15 seconds;
- 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 predominant response behavior of the majority of the animals in the group to the motorized winter vehicle group and associated human activity. Response behaviors were categorized as follows (Chester 1976):

- 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 four of five 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), then the observers categorized the group's response as look/resume. The predominant response behavior was only recorded for those animals within approximately 500 meters of the road.

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).

Stress Levels of Wildlife

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 at approximately 2-week intervals throughout the winter from 35 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 some wildlife populations during 2003. 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. 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 24, 2002. 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.

In addition, we 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 40 cow and calf elk in this portion of the park. 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.

Staff from the Bison Ecology and Management Program, Yellowstone Center for Resources, conducted bi-annual (early winter, summer) aerial surveys of the bison population to estimate abundance (Hess 2002). They also conducted monthly aerial surveys to determine the proportions of the bison population near the park boundary and likely to interact with human recreation.

The Avian Ecology and Management Program, Yellowstone Center for Resources, conducted aerial surveys for eagles and swans each month during November through April. They also conducted bi-weekly ground counts of eagles and swans along two census transects (i.e., Yellowstone River-Yellowstone Lake, and Madison River- Firehole River). The winter use survey crews also completed weekly swan surveys along the Madison River-Firehole road segment and Yellowstone River-Lake road segment, respectively. In addition, biologists from the Avian Ecology and Management Program monitored two traditional nest sites for bald eagles (*Haliaeetus leucocephalus*) in the Madison and Gibbon drainages on a weekly basis. The Madison nest site was located approximately 50 meters from the groomed road and, as a result, was exposed to high-intensity motorized use during winter. In contrast, the Gibbon nest was located >500 meters from the road and, apparently, relatively undisturbed by motorized human use.

The Wolf Restoration Program, Yellowstone Center for Resources, conducted weekly aerial surveys to locate radiocollared wolves (*Canis lupus*) and estimate wolf abundance during December through April. Sizes of packs utilizing various portions of the park near winter use road corridors were estimated by summing all observed individuals in each pack during early (November/December) and late (March) winter. Relocations of radiocollared wolves also provided information regarding their distribution and activities in the vicinity of winter use road corridors.

<u>Statistical Analyses</u>

Dr. John Borkowski, a statistician at Montana State University, developed models to evaluate if variables related to motorized winter use were associated with changes in behavior of bison, elk, and trumpeter swans during winter 2003. The survey and model variables considered in the statistical analyses were as follows: 1) wildlife response category; 2) temperature; 3) cloud cover category; 4) precipitation category; 5) visibility category; 6) habitat type; 7) direction of wildlife travel; 8) perpendicular distance of the nearest animal to the road; 9) number of adult females; 10) number of adult males; 11) number of young; 12) number of unknown age class; 13) predominant wildlife activity; 14) number of 2-stroke snowmobiles involved in a wildlife interaction; 15) number of 4-stroke snowmobiles involved in a wildlife interaction; 16) number of snow coaches involved in a wildlife interaction; 17) number of wheeled vehicles involved in a wildlife interaction; 18) type of guidance associated with the human group (i.e., guided, unguided, administrative); 19) type of human response during a wildlife interaction; 20) duration of the human/wildlife interaction; 21) total number for the species (i.e., number of animals in the group); 22) total number of snowmobiles involved in a wildlife interaction; 23) daily west gate motorized vehicle count; 24) daily south gate motorized vehicle count; and 25) whether the species was on the road during the human/wildlife encounter.

The "wildlife response category" was the response variable 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 three wildlife response categories considered in the models: no response; look and resume response; and active response. The other variables are 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, Dr. Borkowski 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 ratios) are modeled. The number of logits modeled is one less than the number of response levels. Thus, Dr. Borkowski modeled two logits, L_{i0} and L_{i1}, where:

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

By selecting π_{i2} to be in the denominator of each odds ratio, these two logits can be used to model: 1) the odds of a wildlife response requiring a low energy expenditure (i.e., look and resume) compared to 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 a wildlife response requiring negligible or no energy. In other words, Dr. Borkowski assessed whether the odds of a response requiring some energy expenditure relative to a no response probability was associated with changing levels of the study variables. For example, if $L_{i0} = \log(\pi_{i0} / \pi_{i2})$ 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.

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 assumed that the effect of this lack of independence on data-based inferences was minimal.

Dr. Borkowski 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, Dr. Borkowski calculated variance inflation factors to determine if multicollinearity among variables was a potential concern. No multicollinearity problems were detected. 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. These variables were retained in the model so that the two specific management-related questions stated in the Conceptual Approach section of the methods were addressed explicitly in the final model. A maximum likelihood analysis of variance (ML ANOVA) was run to determine if a variable's effect was statistically significant in the generalized logit model.

III. RESULTS

Weather

The snow pack began to accumulate in November, peaked in April, and melted away in May though differences among areas of the park were evident. Maximum daily snow water equivalent peaked at approximately 56 centimeters on the Madison Plateau, 35 centimeters at Canyon, 21 centimeters at West Yellowstone, and 29 centimeters at the Northeast Entrance station (Table 1). In general, average snow water equivalents per month were lower than the overall monthly averages since 1981 for the same locations. Cumulative snow water equivalent during October 1, 2002, through April 30, 2003, was 4,999 centimeters on the Madison Plateau, 1,828 centimeters at West Yellowstone, 4,238 centimeters at Canyon, and 2,596 centimeters at the Northeast Entrance station (Table 1). These totals suggest that the winter of 2003 was relatively moderate. For comparison, the cumulative snow water equivalent value of 4,999 centimeters at the Madison Plateau SNOTEL site during winter 2003 was lower than totals obtained during 28 of the past 36 winters at this site (Figure 1).

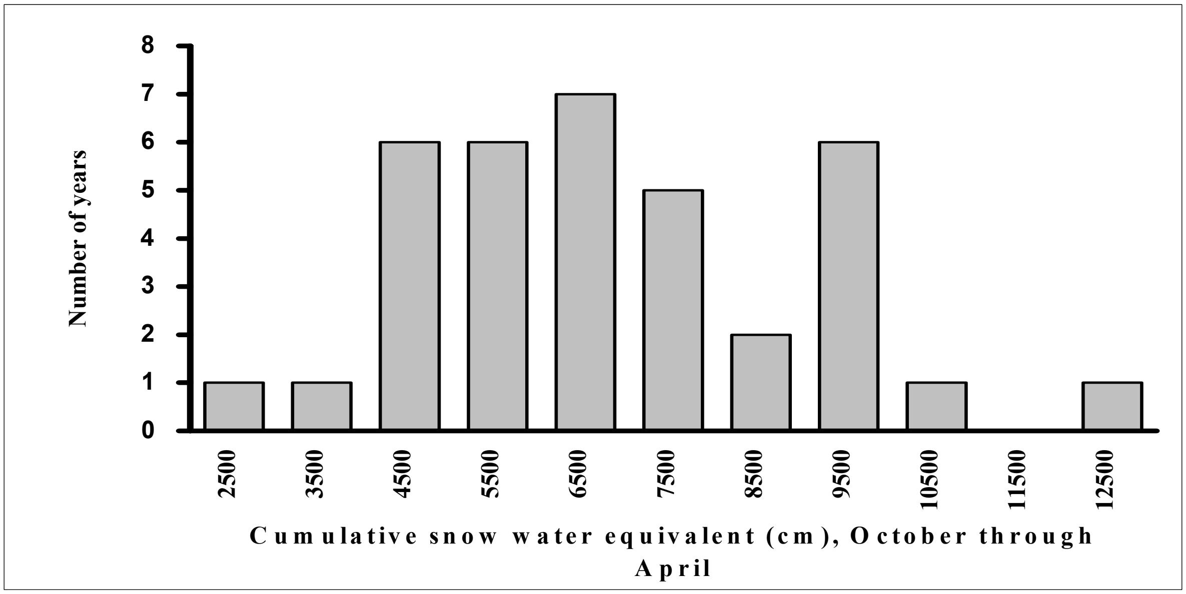


Figure 1. Frequency distribution of the number of winters during 1968-2003 with various cumulative snow water equivalent totals. Daily snow water equivalents were measured at the Madison Plateau SNOTEL site in Montana and summed over days during October 1st through April 30th to obtain the cumulative 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.

Ambient temperatures during surveys ranged from -4°F to 51°F in the Madison area, -12°F to 57°F in the Canyon area, and -3°F to 59°F in the Mammoth area. Only one day during October 1, 2002, through April 30, 2003 (i.e., 212 total days) had a minimum temperature below the effective critical temperature for bison. Minimum temperatures in northern Yellowstone were less than the effective critical temperature for elk on 23 days (i.e., 11% of total days). Minimum temperatures in west-central Yellowstone were less than the effective critical temperature for elk on 16 days (8% of total days). The longest consecutive number of days with minimum temperatures less than the effective critical temperature for elk was four days. These data suggest that temperatures during winter 2003 were relatively moderate for ungulates.

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 a 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 recruitment of elk calves in the central portion of Yellowstone National Park is negatively correlated with snow pack, with the most severe snow pack conditions resulting in the virtual elimination of a juvenile cohort (Figure 3).

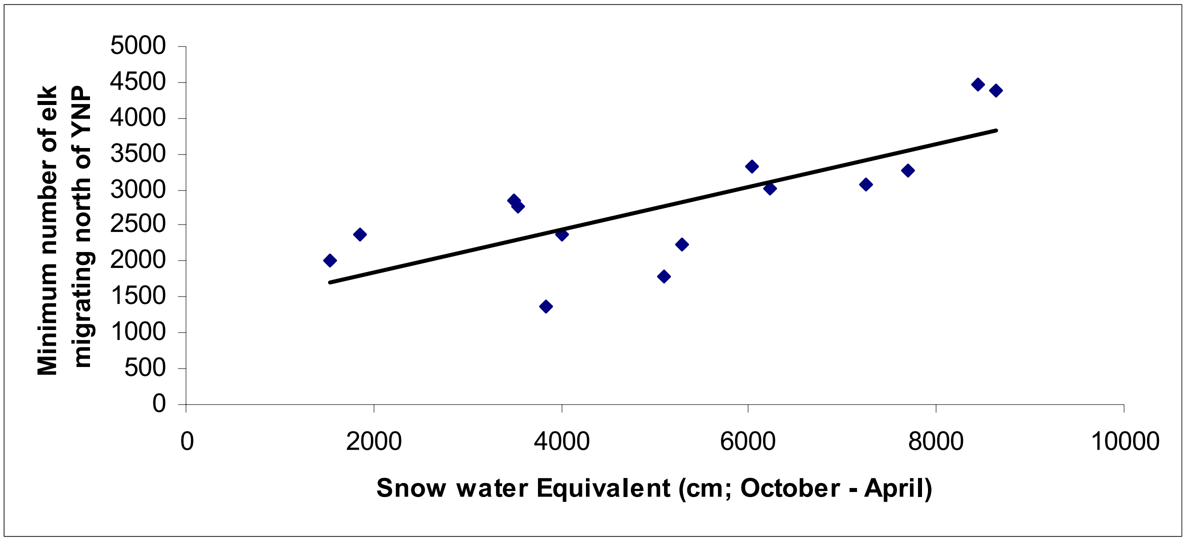


Figure 2. Relationship between cumulative snow water equivalent (cm) during October through April measured at the Northeast Entrance SNOTEL site and migration of northern Yellowstone elk out of Yellowstone National Park during 1989-2002.

Motorized Winter Use

The public over-the-snow vehicle season was 80 days from December 17, 2002, through March 7, 2003. The dry, warm winter weather pattern of 2002-2003 delayed opening dates for over-the-snow vehicle travel. Only the road segment from the south entrance station to Old Faithful had accumulated sufficient snow to allow over-the-snow vehicle traffic by the scheduled opening date on December 17, 2002. Road segments surveyed during our winter use monitoring did not open until 10 days later, and the Mammoth to Norris road segment did not open to snowmobile traffic until the first week of January.

Lack of sufficient snow depth and occasional blowing or drifting snow periodically limited over-the-snow vehicle travel in some areas of the park. During the 2003 season, drifting snow closed survey segments in the Hayden Valley twice and Swan Lake Flats once for safety reasons. Lack of snow buildup combined with heavy over-the-snow vehicle traffic closed the West Yellowstone to Old Faithful and Mammoth to Norris road segments intermittently during December and January.

Interior road segments closed to public use on March 9, 2003. At that time, grooming operations ceased and plowing began. Plowing operations began at Mammoth Hot Springs and moved southward. Thus, the arrival of plows and snow removal equipment at each road segment varied.

Total numbers of over-the-snow vehicles that entered each station were as follows (Appendix B):

Gate	Guided Groups	Guided Snowmobiles	Unguided Snowmobiles	Snow coaches
East Entrance	6	17	846	0
West Entrance	358*	887	21424	762
South Entrance	766	5361	4137	368

* Due to staffing limitations and high traffic volume, staff at the West Entrance Station did not consistently count guided groups. This number reflects reports by guide companies to the Business Management Office at Yellowstone National Park.

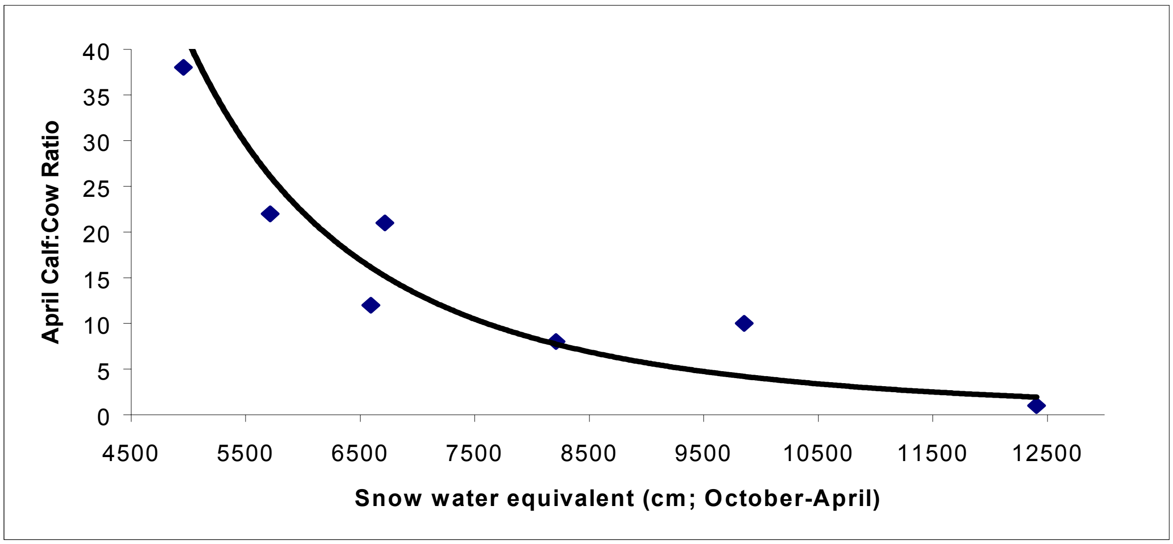


Figure 3. Relationship between cumulative snow water equivalent (cm) during October through April measured at the Madison Plateau SNOTEL site and an index of winter survival for central Yellowstone elk calves during 1992-1998 (i.e., prior to wolf re-establishment in this area).

The average and peak daily numbers of total over-the-snow vehicles entering each station were as follows (Appendix B):

	Average number of snowmobiles	Average number of snow coaches	Maximum no. of snowmobiles	Maximum no. of snow coaches
West Entrance	310	11	558	59
South Entrance	140	5	239	29
East Entrance	14	0	52	0

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	MAY
West Yellowstone SNOTEL Site								
Average SWE per Month, 2003	0.1	2.2	5.4	10.7	16.7	18.8	6.9	0.1
Average SWE per Month, 1981-2000	0.4	3.1	10.2	16.9	22.9	28.1	22.4	2.5
2003 Percent of Average (1981-2000)	29	70	53	63	73	67	31	4
Maximum SWE per Month, 2003	0.8	4.1	8.6	15.2	18.5	20.8	17.3	0.5
Cumulative SWE, 2003	1.8	69.1	237.5	568.7	1036.1	1619.0	1827.3	1828.0
Madison Plateau SNOTEL Site								
Average SWE per Month, 2003	1.1	5.9	11.3	22.0	33.0	42.2	50.8	42.8
Average SWE per Month, 1981-2000	1.6	8.5	21.8	33.7	45.0	55.6	61.3	42.8
2003 Percent of Average (1981-2000)	67	69	52	65	73	76	83	99
Maximum SWE per Month, 2003	3.6	7.9	18.3	29.7	36.6	47.2	51.6	56.4
Cumulative SWE, 2003	33.0	209.8	561.1	1243.8	2166.9	3474.0	4998.7	6325.1
Canyon SNOTEL Site								
Average SWE per Month, 2003	1.3	4.5	8.6	14.9	23.9	31.2	32.8	23.0
Average SWE per Month, 1981-2000	0.6	4.4	11.5	18.6	24.8	31.1	32.6	15.5
2003 Percent of Average (1981-2000)	203	102	75	80	97	99	99	148
Maximum SWE per Month, 2003	2.8	7.1	11.7	20.8	26.2	34.5	30.7	33.3
Cumulative SWE, 2003	39.6	175.0	441.5	904.7	1572.5	2539.5	3524.0	4238.0
Northeast Entrance SNOTEL Site								
Average SWE per Month, 2003	0.3	2.1	4.9	9.5	18.8	25.8	21.5	3.4
Average SWE per Month, 1981-2000	0.2	2.8	8.4	14.4	19.6	24	21.3	5.1
2003 Percent of Average (1981-2000)	143	75	58	66	96	107	99	67
Maximum SWE per Month, 2003	0.8	4.1	6.6	15.5	21.6	28.7	29.0	11.2
Cumulative SWE, 2003	8.1	72.4	222.8	516.6	1042.9	1843.8	2490.0	2595.6

Peak visitation typically occurred on weekends and holidays, while fewer vehicles entered the park on weekdays. During winter 2003, the number of snowmobiles entering the West Entrance Station exceeded 550 machines, which is the daily snowmobile entry limit for the winters of 2004 and 2005, on only one day (i.e., February 20th, 558 machines, Appendix B). The numbers of snowmobiles entering the South and East Entrance Stations during winter 2003 did not exceed the daily snowmobile entry limits for each station during the winters of 2004 and 2005 (i.e., South = 250 snowmobiles; East = 100 snowmobiles; Appendix B).

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). The cumulative total of over-the-snow vehicles entering the West Entrance Station surpassed 7,500 vehicles on January 20th during winter 2003 (Figure 4).

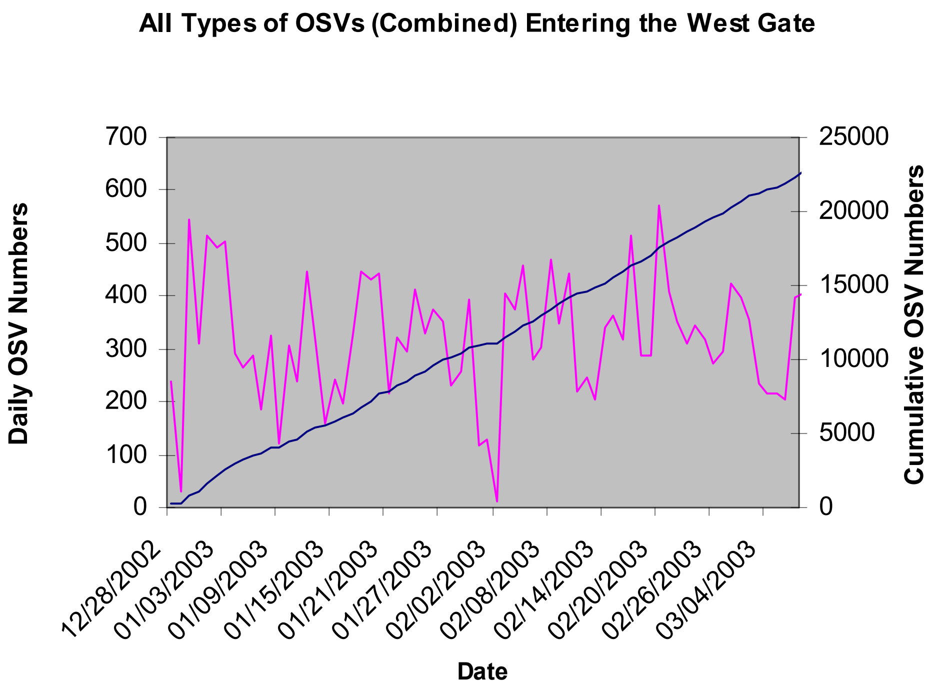


Figure 4. Daily and cumulative numbers of total over-the-snow vehicles (OSVs; i.e., snow coaches, unguided snowmobiles, commercially guided snowmobiles) entering the West Entrance Station of Yellowstone National Park during winter 2003.

Over-the-snow vehicle traffic typically was influenced by an interaction between time and location. Rental and guided snowmobiles typically did not leave gateway communities until 0700 or later. Also, most traffic typically exited the park before dark because a 2100 to 0700 closure was enforced for the first time during winter 2003. As a result, road segments in the vicinity of Madison had peak traffic early in the morning 0800-1000 and during approximately 1600-1800, while the majority of traffic in the park interior (e.g., Canyon) was during 1000-1600.

Use of snow coach-only areas varied substantially among routes. For example, Riverside Drive and Virginia Cascades were frequently used by snow coaches, whereas no coaches used Lake Butte Overlook. Interactions between snow coaches and wildlife on snow coach routes was low. No interactions between wildlife and snow coaches occurred along the Canyon snow coach routes.

Human Behavior and Wildlife Responses

Monitoring efforts began on December 26, 2002, and continued until April 18, 2003, approximately seven 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 2003 was $125,000 (Appendix C).

Winter use crews conducted 332 surveys of road segments, covering 11,182 kilometers. Observers recorded 4,269 groups of wildlife during these surveys, including 908 groups of elk, 2,294 groups of bison, 447 groups of swans, and 620 groups of other species (e.g., coyotes, bald eagles, wolves, etc). Observers recorded human behaviors and the responses of wildlife to motorized winter use vehicles during 3,020 interactions. No groups of wildlife were observed during 30 surveys of road segments. Summaries of observed wildlife groups and interactions by road segment and survey crew are provided in Appendix D.

For some comparisons and presentation of data, we categorized road segments as "high" or "low" use by wildlife and over-the-snow vehicles based on the frequency of observed wildlife groups and interactions with over-the-snow vehicles per kilometer surveyed (Table 2). The following road segments were categorized as having high use by wildlife and over-the-snow vehicles: 1) Madison to West Yellowstone; 2) Madison to Old Faithful; and 3) Canyon Village to Lake Butte. The following road segments were categorized as having low use by wildlife and over-the-snow vehicles: 1) Mammoth to Norris; 2) Norris to Madison; 3) Canyon Village to Norris; and 4) Fishing Bridge to West Thumb. The wheeled vehicle (i.e., plowed) road segment from Mammoth to Lamar Valley was treated separately in analyses.

Groups of snowmobiles and snow coaches were involved in 43 (n = 1,300) and 6 (n = 167) percent, respectively, of the observed wildlife-human interaction events with wildlife during winter 2002-2003. The remaining 51 percent (n = 1,553) of observed interactions involved wheeled vehicles on plowed roads.

Human Behaviors: A total of 810 interaction events between ungulates (bison and elk) and over-the-snow vehicles and associated humans were documented when animal groups were off the roads, including 710 groups of snowmobiles and 100 groups of snow coaches. During these interactions, 259 groups of snowmobiles and 42 groups of snow coaches stopped on the road to view animals. Thirty-three percent of snowmobile riders that stopped stayed on their machines, while 67 percent dismounted. Forty-one percent of the snowmobile riders that dismounted their machines approached wildlife. Of the snowmobile riders that approached wildlife, 65 percent remained >25 meters from animals. Riders in 48 percent of the snow coaches that stopped stayed in their coaches, while 52 percent dismounted. Sixty-four percent of the snow coach riders that dismounted approached wildlife. Of the snow coach riders that approached wildlife, 57 percent remained >25 meters from animals.

Table 2. Summary of observed wildlife groups and interactions with motorized winter use vehicles by kilometers (km) surveyed for each road segment during winter 2003, Yellowstone National Park, Wyoming.

Road Segment	**Total Kilometers Surveyed**	**Wildlife Groups Observed**	**Groups Observed per Kilometer Surveyed**	**Interactions Observed**	**Interactions Observed per Kilometer Surveyed**	**Wildlife and Human Use Category**
Madison to West Yellowstone (23 km)	1305	697	0.53	645	0.49	High
Madison to Old Faithful (26 km)	1451	984	0.68	863	0.59	High
Mammoth to Norris (34 km)	655	94	0.14	64	0.10	Low
Norris to Madison (23 km)	998	162	0.16	123	0.12	Low
Mammoth to the Lamar Valley (60 km)	3570	1336	0.38	706	0.20	Wheeled Vehicle
Canyon Village to Norris (19 km)	590	25	0.04	19	0.03	Low
Fishing Bridge to West Thumb (34 km)	1134	73	0.06	56	0.05	Low
Canyon Village to Lake Butte (40 km)	1506	888	0.59	538	0.36	High
Fishing Bridge to Sylvan Pass		10		6		Discontinued

We also compared human behavior during interactions with wildlife (i.e., bison, elk, swans) among over-the-snow vehicles in commercially guided groups (including snowmobiles and snow coaches), unguided groups of snowmobiles, wheeled vehicles, and administrative groups (i.e., park and concessionaire staff) (Appendix E). The behavior of over-the-snow vehicles and associated humans in response to wildlife groups was typically 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, 5% stop/resume, 13% stop and observe for an extended period, 13% dismount over-the-snow vehicles, 8% approach wildlife, 1% impede and/or hasten wildlife, and 1% undetermined. Qualitative comparisons (Appendix E) suggest that the behaviors of visitors were similar between low and high intensity use areas, and those associated with snowmobiles or snow coaches. There was an apparent tendency for visitors in commercially guided snowmobile groups to approach wildlife more frequently than visitors in unguided snowmobile groups. Also, there appeared to be a tendency for administrative users (both over-the-snow and wheeled vehicles) to stop and observe swans more frequently than visitors. In addition, there was an apparent tendency for visitors in wheeled vehicles on the plowed road segment to respond less often to groups of wildlife than visitors on over-the-snow vehicles. These apparent differences must be viewed cautiously, however, because some of our sample sizes (e.g., guided groups) were quite small. Additional data from one or more winter seasons will be necessary to establish the reliability of these apparent differences.

During wildlife-visitor snowmobile interaction events when animal groups were off the roads, 23 of 54 groups (43%) of commercially guided snowmobiles and 294 of 895 groups (33%) of unguided snowmobiles stopped on the road to view bison, elk or swans. Of those visitors that stopped, seventeen percent of guided riders stayed on their snowmobiles, while 83 percent dismounted. Sixty-eight percent of guided riders that dismounted approached wildlife. Of the guided snowmobile riders that approached wildlife, 62 percent remained >25 meters from animals. Thirty-seven percent of the unguided riders stayed on their snowmobiles, while 63 percent dismounted. Thirty-six percent of the unguided riders that dismounted approached wildlife. Of the unguided snowmobile riders that approached wildlife, 67 percent remained >25 meters from animals. Thus, there was an apparent tendency for visitors in guided snowmobile groups to dismount and approach wildlife with a greater frequency than visitors in unguided snowmobile groups. This apparent difference may be misleading or nonexistent, however, owing to the relatively small sample of guided groups compared to unguided groups. Additional data from one or more winter seasons will be necessary to establish the reliability of these apparent differences.

Wildlife Responses: The responses of wildlife to over-the-snow vehicles and associated human were typically minor, with 61% of the 1,315 total observed wildlife responses categorized as no apparent response, 23% look/resume, 5% attention/alarm, 8% travel, 2% flight, and 1% defense (Appendix F). We plotted the total proportions of no apparent response, look/resume, attention/alarm, travel, flight, and defense of wildlife (i.e., bison, elk, swans) against categorical levels of over-the-snow vehicles that entered the West Entrance Station as an index of trends related to increasing motorized winter use. For these comparisons, wildlife responses were combined for observations along the Madison to West Yellowstone, Madison to Old Faithful, and Madison to Norris road segments. Bison rarely responded to human activity along roads, with 78% of the 521 responses categorized as no apparent response, 13% look/resume, 2% attention/alarm, 6% travel, and 1% flight (Appendix G). Elk responded more often than bison to motorized use and human activity along roads, with 32% of the 208 responses categorized as no apparent response, 42% look/resume, 16% attention/alarm, 9% travel, 1% flight (Appendix G). Similarly, swans responded more often than bison to motorized use and human activity along roads, with 42% of the 166 responses categorized as no apparent response, 36% look/resume, 4% attention/alarm, 15% travel, and 3% flight (Appendix G).

Wildlife responses to motorized winter use and associated human behaviors were species dependent. For example, the likelihood of observing an active response by bison and swans (but not for elk) increased as the numbers of snowmobiles in a group increased. Also, the likelihood of observing an active response by elk and swans (but not for bison) increased as the numbers of snow coaches in a group increased. The estimated odds of observing an active response relative to no response by elk and swans were significantly higher when humans either dismounted and/or approached wildlife. Similarly, the estimated odds of observing a look and resume response relative to no response were significantly higher when humans stopped to watch bison than when they continued driving.

Wildlife responses varied by species among commercially guided, unguided, and administrative groups during winter 2003. For example, the estimated odds of observing an active response relative to no response by bison were significantly higher for a commercially guided group than for an unguided group (under identical conditions). Conversely, the estimated odds of observing a look and resume response or an active response relative to no response by elk was significantly lower for a commercially guided group than for an unguided group. The estimated odds of observing a look and resume response or active response relative to no response by bison and elk was significantly higher for administrative traffic than for an unguided group. Furthermore, there were no statistically significant results among comparisons of swan responses to commercially guided, unguided, and administrative groups. This result implies that either there was no positive or negative association between swan response and guide status, or that sample sizes during winter 2003 were too small to detect associations.

We suspect that these somewhat inexplicable variations in associations among wildlife responses and guide status results from the relatively low sample of guided groups (<10% of cases) compared to unguided groups. Thus, these apparent differences must be viewed cautiously because they may be misleading or nonexistent. By collecting data over several winter seasons, we can reexamine this issue with an increased sample size to establish the reliability of these apparent differences.

Statistical analyses by Dr. Borkowski indicated that several other variables likely influence the odds of a response by bison, elk, and/or swans to motorized winter use. These variables include group size, habitat type, precipitation, visibility, wildlife activity (e.g., standing v. bedded), ambient temperature, interaction time, and daily numbers of motorized vehicles entering the south and west gates. For example, for each 10-animal increase in the size of a wildlife group during winter 2003, the estimated odds of observing no response relative to a look and resume response were significantly higher for both bison and elk. By collecting data 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 canid and otter groups were observed during our surveys. Wolves were observed on 54 occasions and during 27 interactions with motorized winter vehicles and associated humans. Wolves traveled away from humans in 12 interactions (44%), fled humans in one interaction (3%), and displayed alarm in one instance (i.e., visitors approached wolves with a domestic dog). Coyotes were observed on 223 occasions and during 154 interactions with motorized winter vehicles and associated humans. Coyotes traveled away from humans in 45 interactions (35%), fled humans in 7 interactions (15%), and displayed alarm in 6 interactions (13%). Otters were observed on 5 occasions and during 2 interactions with motorized winter vehicles and associated humans. Otters were minimally affected (i.e., no reaction or look-resume) during those interactions. 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 35 occasions during our surveys, including 14 bison groups, 16 coyote groups, and 5 elk groups. Wildlife were not trapped by, or forced to jump over, snow berms along the sides of the road during any of these observations.

Ungulate Use of Groomed Roads: Bison were observed on groomed roads during 159 of 1,668 observations of bison groups from December 27, 2002, through March 10, 2003. Thus, the vast majority of observed bison groups were using areas off the groomed roads. One hundred and twenty of the bison groups observed on groomed roads were traveling, whereas 36 groups were stationary and 3 groups were resting. Bison use of groomed roads occurred throughout the daylight survey hours, with no apparent peak time of road use (Figure 5).

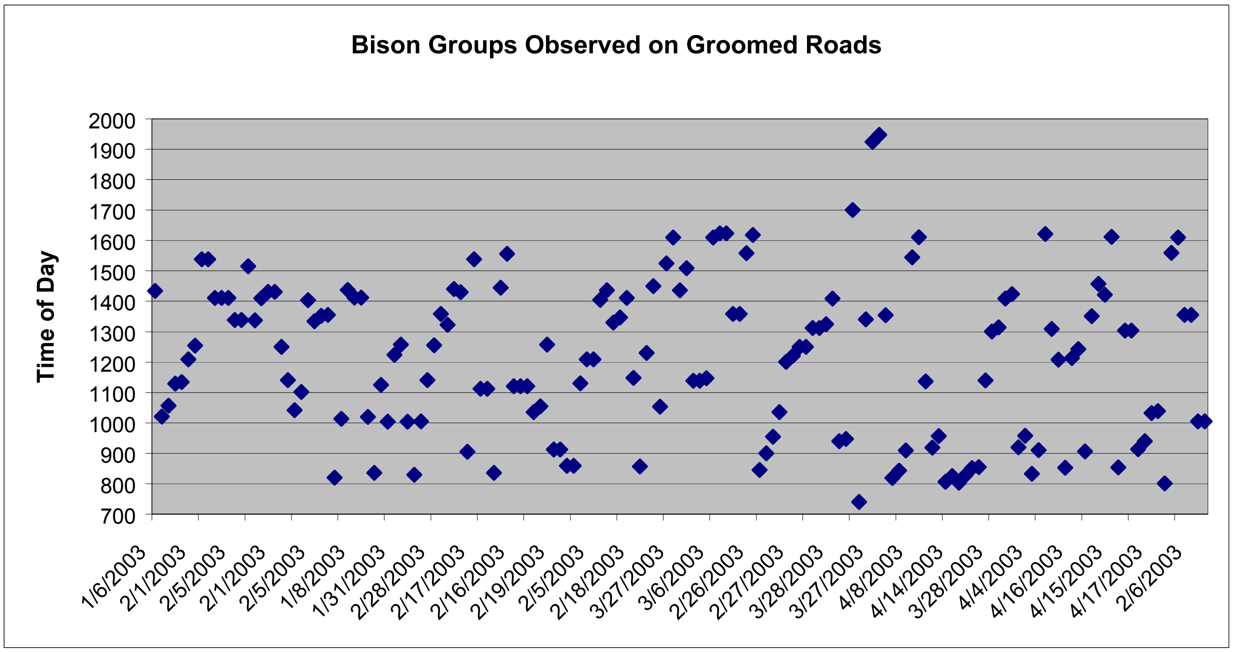


Figure 5. Timing of bison use of groomed roads during daylight survey hours, winter 2003, Yellowstone National Park, Wyoming.

Elk were observed on groomed roads during 10 of 424 observations of elk groups from December 27, 2002, through March 10, 2003. Thus, elk appeared to utilize road corridors less than bison in winter 2003. Much like bison, however, the vast majority of observed elk groups were using areas off the groomed roads. Nine of the elk groups observed on groomed roads were traveling, whereas 1 group was stationary and none were resting.

A total of 95 interaction events between ungulates and over-the-snow vehicles and associated humans were documented when animal groups were <u>on</u> the groomed roads, including 75 groups of snowmobiles and 20 groups of snow coaches. The estimated odds of observing an active response relative to no response was 20 times greater when bison were on the road than when they were off the road. Thirteen percent of these snowmobile groups impeded or hastened wildlife movement. None of the guided snowmobile (n = 4) groups and 14 percent (10 of 71) of the unguided snowmobile groups impeded or hastened wildlife movements. Twenty-five percent of these snow coach groups impeded or hastened wildlife movement.

Wildlife Distances from Roads: We recorded numbers of animals and distances from roads for the nearest animal in 1,125 groups of bison, 233 groups of elk, and 366 groups of swans. Mean distances to the nearest animal in bison, elk, and swan groups from roads were 230, 137, and 128 meters, respectively. On average, swans were observed closer to roads because the road systems are typically located close to rivers. Mean distances (± SD) of bison and elk groups along each of the study area road segments, when plotted against categories of daily over-the-snow vehicle traffic entering the West Entrance Station, do not indicate avoidance of the road as over-the-snow vehicle traffic increased (Appendix H). However, wildlife groups located closer to motorized winter use corridors exhibited increased responses to over-the-snow vehicle traffic and associated human behaviors (Figure 6). Behavioral responses of wildlife decreased as distance from motorized winter use corridors increased. The estimated odds of observing no response relative to either a look and resume or active response by bison, elk, and swans was significantly higher for each 100 meter increase in distance from the road.

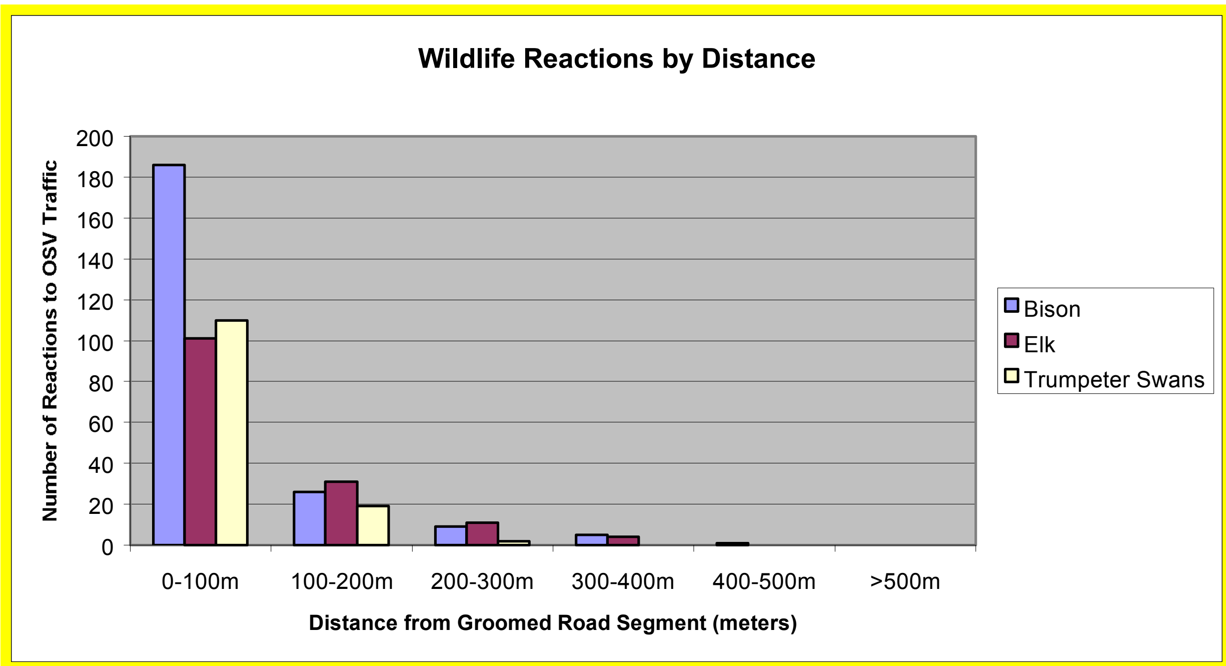


Figure 6. The number of visible reactions (i.e., look-resume, travel, alarm-attention, flight, or defense) displayed by groups of bison, elk, or swans near groomed road segments in Yellowstone National Park during winter 2002-2003.

Vehicle-caused Wildlife Deaths or Injuries

During winter 2002-2003, eleven animals were either killed directly during motorized vehicle collisions or euthanized as a result of such collisions. One bison and one coyote were killed in the Madison area by snowmobiles. In addition, one mountain lion kitten was killed in this area by wheeled vehicle traffic before the motorized winter season began. One elk, one coyote, and one bison were killed in the Mammoth area by wheeled vehicles. Two coyotes and three bison were killed in the Canyon area by snowmobiles.

Stress Levels of Wildlife

One hundred and five fecal samples were collected from 35 radio-collared elk of known ages in west-central portion of Yellowstone National Park during winter 2003. We have contracted with Drs. Robert Garrott and 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 contracted to be completed by September 30, 2003, however, laboratory constraints may delay them until spring 2004. 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 and 384 elk in April 2003. The autumn elk population in 2002, as estimated by combining the mean spring estimate for 2002 with the autumn sex-age composition survey, was 464 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 7, Garrott et al. 2003).

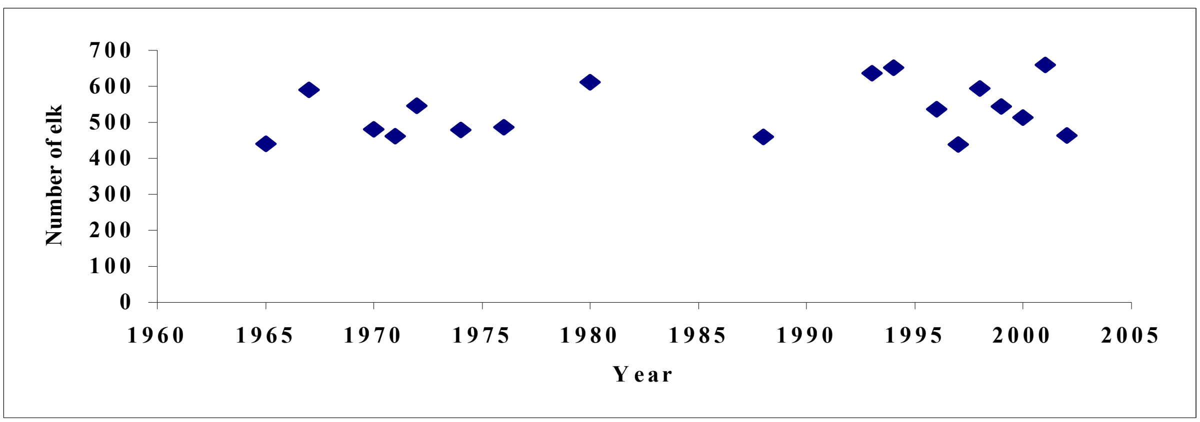


Figure 7. Estimates of abundance for central Yellowstone elk during 1965-2003, Yellowstone National Park, Wyoming.

A total of 9,215 northern Yellowstone elk were counted during the December 24, 2002, survey, including 2,318 elk (25 percent) north of the boundary of Yellowstone National Park and 6,897 elk (75 percent) inside the park. Elk groups were widely dispersed at higher elevations than typically observed during a survey count in December; likely due to the extremely mild winter conditions. Also, there was generally less than eight inches of snow on north facing slopes at higher elevations and bare to patchy snow conditions on south facing slopes and at lower elevations. This lack of complete snow cover created a brown or mottled background on the landscape that made elk difficult to detect. Thus, survey conditions were considered poor and likely resulted in an inaccurate count.

Despite poor counting conditions this year, the long-term trend in counts of northern Yellowstone elk suggests that the population has decreased since 1988 (Figure 8). 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.

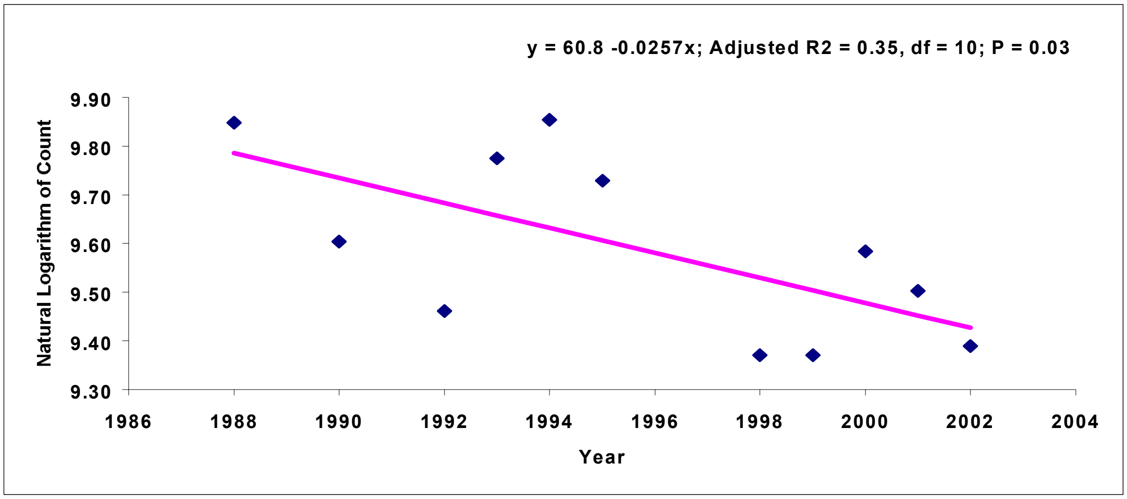


Figure 8. Trend of logarithm-transformed population counts of northern Yellowstone elk during 1988 to 2002.

Staff from the Bison Ecology and Management Program, Yellowstone Center for Resources, conducted aerial surveys of the bison population on November 5/6, 2002, and March 20/24, 2003, to estimate abundance. Total bison counted during these flights were 3,781 bison on November 5th, 3,604 bison on November 6th, 3,013 bison on March 20th, and 3,003 bison on March 24th (Table 3, Figure 9).

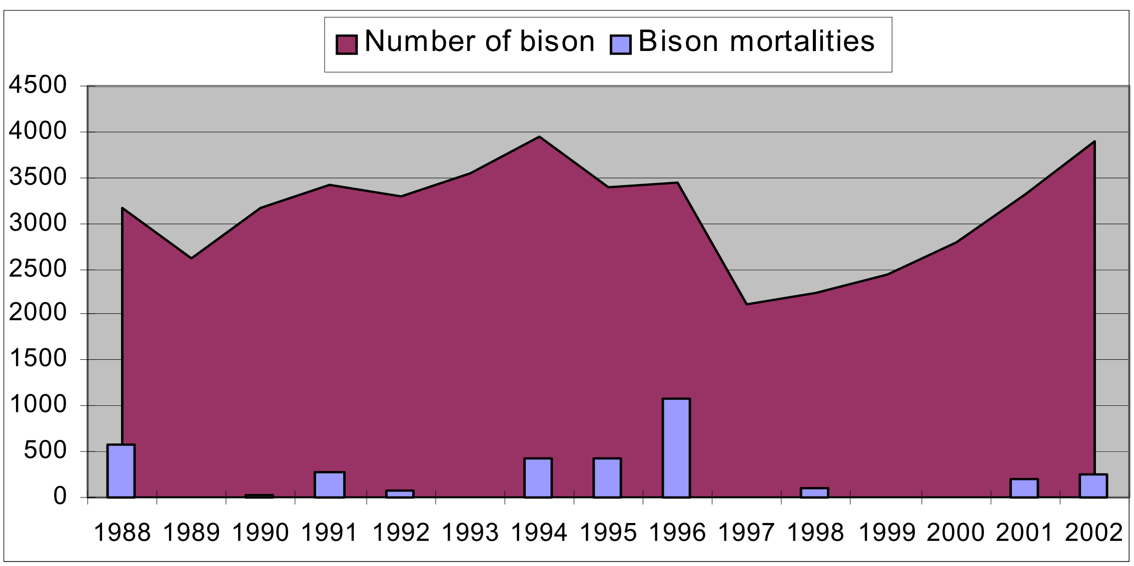


Figure 9. Trend in counts of Yellowstone bison during 1988-2002, Yellowstone National Park, Wyoming.

Table 3. Bison numbers observed by geographical areas during population monitoring flights in Yellowstone National Park, 2002-2003.

Geographical Area	**Total number of bison observed**			
	11/5/02	**11/6/02**	**3/20/03**	**3/24/03**
Northern Range	722	701	978	1,044
Outside Park	0	0	33	36
Hellroaring/Mammoth/Reese Creek	2	17	211	310
Tower Jct. to East end Lamar Canyon	563	557	631	613
Upper Lamar (East end Lamar Canyon to Round Prairie)	36	34	45	39
Swan Lake Flats to Roaring Mountain	121	93	58	46
Pelican Valley	499	498	198	188
Mary Mountain	2,560	2,405	1,837	1,771
Hayden Valley	1,552	1,385	668	389
Old Faithful/Firehole /Nez Perce Complex	312	307	921	1,112
Norris to Madison	321	334	113	171
Madison Jct. to 7-mile Bridge	107	87	106	10
7-mile Bridge to West Entrance	268	292	29	89
Outside Park	0	0	0	0
TOTAL BISON COUNTED	**3,781**	**3,604**	**3,013**	**3,003**

At the beginning of winter 2003, there were approximately 148 wolves in 14 packs were present in Yellowstone National Park (Table 4, Smith et al. 2003). The Swan Lake, Leopold, Geode, Buffalo Fork, Agate, and Druid packs inhabited ranges that were traversed by or near the plowed road segment from Mammoth to Cooke City and, as a result, were exposed to wheeled vehicle use during winter 2003. The Cougar Creek and Nez Perce packs inhabited ranges that were traversed by the groomed road segments in the west-central portion of the park. Thus, these packs were exposed to over-the-snow vehicle use during winter 2003. Aerial wolf locations collected during winter 2003 suggest that wolves did not avoid motorized winter use corridors at a landscape scale (Figure 10). Analyses at a finer scale have not been conducted.

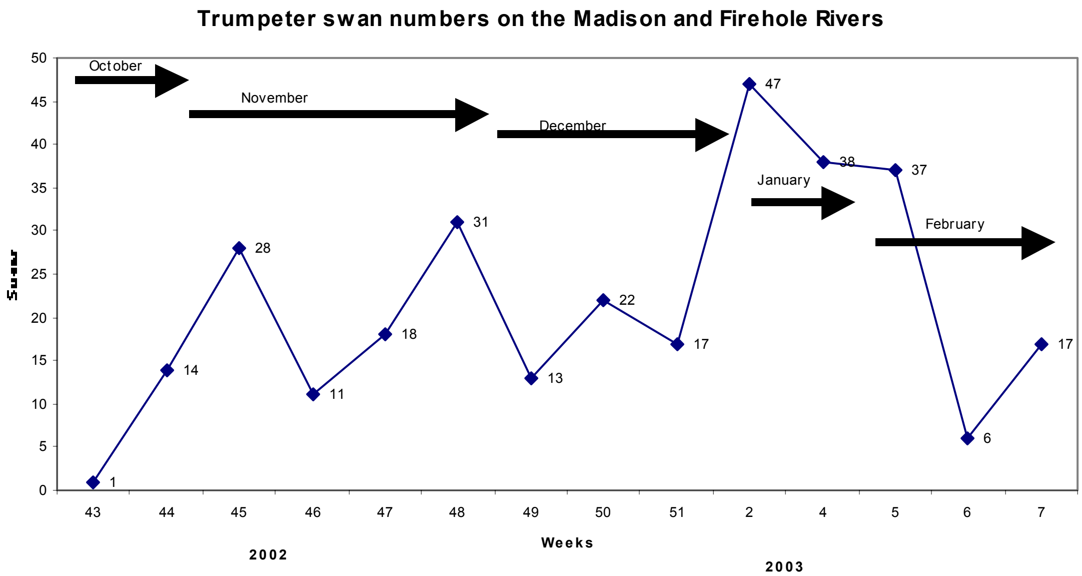
Counts of trumpeter swans on the north and west shores of Yellowstone Lake and along the Yellowstone River peaked in late November at 496 swans, and decreased relatively consistently through late February as open water sections of the Yellowstone River diminished (Figure 11; T. McEneaney, Yellowstone Center for Resources, unpublished data). Conversely, counts of trumpeter swans along the Madison and Firehole Rivers increased during late December, peaked at 47 swans in mid-January, and remained relatively high through early February (Figure 11). As the winter progressed, and open water areas in the park diminished, the proportion of the swan population counted within Yellowstone National Park decreased as compared to areas outside the park (Table 5). Thus, relatively fewer swans were exposed to motorized winter use in the park.

Table 4. Summary of wolf population in Yellowstone National Park, Wyoming, during October-December 2002.

Pack	Adults/ Yearlings	Pups	Estimated Pack Size	General Location
AGATE CREEK	6	4	10	AGATE TO ANTELOPE CREEKS, YNP
BECHLER GROUP	2	2	4	BECHLER REGION, YNP
CHIEF JOSEPH	2	8	10	W/NW YELLOWSTONE NATIONAL PARK
COUGAR CREEK	5	5	10	WESTERN YELLOWSTONE NATIONAL PARK
DRUID PEAK	8	3	11	LAMAR VALLEY TO HELLROARING CREEK, YNP
GEODE CREEK	6	3	9	GEODE CREEK, YNP
LEOPOLD	8	8	16	BLACKTAIL PLATEAU TO MT EVERTS, YNP
MOLLIE'S	10	2	12	PELICAN VALLEY, YNP
NEZ PERCE	15	3	20	CENTRAL YNP
ROSE CREEK II	7	3	10	HELLROARING CRK TO CREVICE CRK, YNP
SLOUGH CREEK GROUP	4	0	4	SLOUGH CREEK, YNP
SWAN LAKE	5	11	16	GARDNER'S HOLE/SWAN LAKE FLAT AREA, YNP
TOWER	2	0	2	TOWER AREA, YNP
YELLOWSTONE DELTA	10	4	14	THOROFARE REGION, YNP
14 Packs	**90**	**58**	**148**	

INSERT FIGURE 10 AERIAL WOLF LOCATIONS

Figure 10. Aerial wolf locations during winter 2003 in relationship to human motorized winter use corridors, Yellowstone National Park, Wyoming.



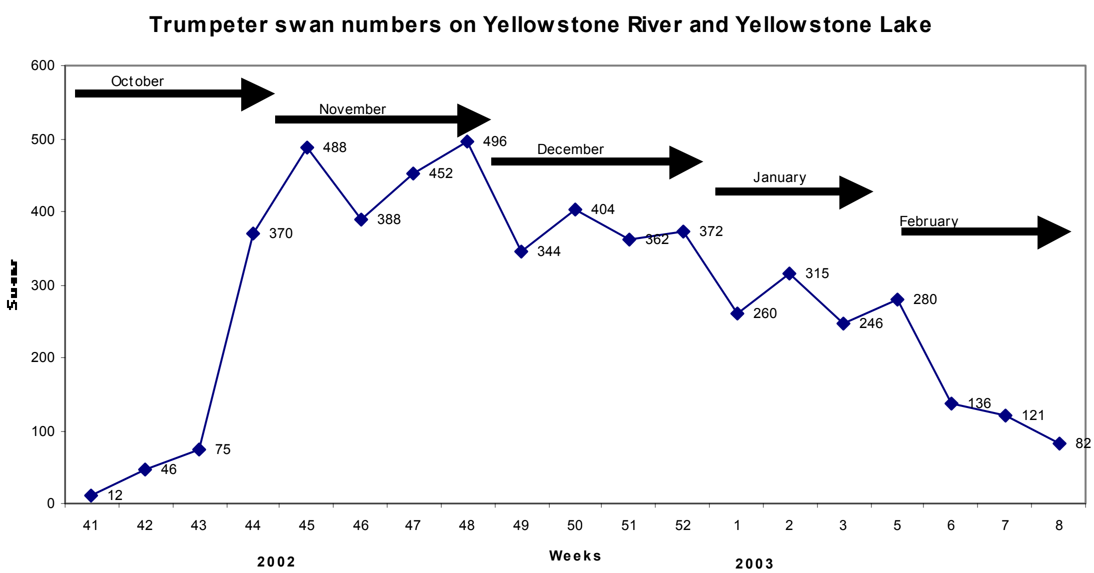


Figure 11. Trends in trumpeter swan counts in the Yellowstone River-Yellowstone Lake and Madison-Firehole Rivers during winter 2003 in Yellowstone National Park, Wyoming.

Table 5. Aerial survey counts of trumpeter swans in and near Yellowstone National Park, Wyoming, during winter 2003.

Survey Date	Area	Adults	Cygnets	Total
November 29	Yellowstone NP	**789**	**144**	**933**
	Yellowstone River and Lake	413	83	496
	Madison and Firehole Rivers	12	3	15
	Other areas within the park	364	58	422
	Outside Yellowstone NP	**333**	**43**	**376**
	Paradise Valley	Not Surveyed		
	Hebgen Lake	333	43	376
	Wyoming (e.g., Flagg Ranch, Snake River)	Not Surveyed		
January 28	Yellowstone NP	**324**	**56**	**380**
	Yellowstone River and Lake	247	33	280
	Madison and Firehole Rivers	22	13	35
	Other areas within the park	55	10	65
	Outside Yellowstone NP	**522**	**66**	**588**
	Paradise Valley	Not Surveyed		
	Hebgen Lake	522	66	588
	Wyoming (e.g., Flagg Ranch, Snake River)	Not Surveyed		
February 11	Yellowstone NP	**146**	**34**	**180**
	Yellowstone River and Lake	98	23	121
	Madison and Firehole Rivers	13	4	17
	Other areas within the park	35	7	42
	Outside Yellowstone NP	**487**	**45**	**532**
	Paradise Valley	23	5	28
	Hebgen Lake	462	40	502
	Wyoming (e.g., Flagg Ranch, Snake River)	2	0	2
April 8	Yellowstone NP	**28**	**4**	**32**
	Yellowstone River and Lake	17	3	20
	Madison and Firehole Rivers	0	0	0
	Other areas within the park	11	1	12
	Outside Yellowstone NP	**248**	**36**	**284**
	Paradise Valley	Not Surveyed		
	Hebgen Lake	248	36	284
	Wyoming (e.g., Flagg Ranch, Snake River)	Not Surveyed		

IV. Discussion

The winter of 2003 was relatively mild in terms of snow pack and ambient temperatures. In general, average snow water equivalents (i.e., the amount of water in the snow) per month were lower than the overall monthly averages since 1981. For example, the cumulative snow water equivalent value of 4,999 centimeters at the Madison Plateau SNOTEL site during winter 2003 was lower than totals obtained during 28 of the past 36 winters at this site. Similarly, ambient temperatures during winter 2003 were relatively moderate for ungulates. Only one day had a minimum temperature below the approximate effective critical temperature for bison (i.e., $-34^{o}F$), and <12% of total days were less than the effective critical temperature for elk (i.e., $0^{o}F$).

Mild winter conditions contributed to relatively low motorized use by visitors during winter 2003 compared to previous winters. The number of snowmobiles entering the West Entrance Station exceeded 550 machines, which is the daily snowmobile entry limit for the winters of 2004 and 2005, on only one day. The numbers of snowmobiles entering the South and East Entrance Stations during winter 2003 did not exceed the daily snowmobile entry limits for each station during the winters of 2004 and 2005 (i.e., South = 250 snowmobiles; East = 100 snowmobiles). The cumulative total of over-the-snow vehicles entering the West Entrance Station surpassed 7,500 vehicles on January 20th during winter 2003. In contrast, this threshold was reached on December 31st during the winters of 1999 and 2000.

The behavior of over-the-snow vehicles and associated humans in response to wildlife groups during winter 2003 was typically 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, 5% stop/resume, 13% stop and observe for an extended period, 13% dismount over-the-snow vehicles, 8% approach wildlife, 1% impede and/or hasten wildlife, and 1% undetermined. There were no substantial differences between the behaviors of humans associated with snowmobiles or snow coaches. These results were similar to those reported by Jaffe et al. (2002).

The responses of wildlife to over-the-snow vehicles and associated humans during winter 2003 was typically minor, with 61% of the 1,315 total observed responses by groups of bison, elk, and swans categorized as no apparent response, 23% look/resume, 5% attention/alarm, 8% travel, 2% flight, and 1% defense. However, behavioral responses of wildlife increased as distance from motorized winter use corridors decreased. These results were similar to those reported by Aune (1981), Hardy (2001), and Jaffe et al. (2002). For example, 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 detectable response to over-the-snow vehicles. Fifteen percent of the groups that exhibited a detectable response merely looked at the over-the-snow vehicles and associated humans and resumed their activity. The probability that either bison or elk would respond to over-the-snow vehicles decreased as motorized use increased (Hardy 2001). 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 detectable response to over-the-snow vehicles. Sixty-eight percent of the animals that exhibited a detectable response merely looked at the over-the-snow vehicles and associated humans and resumed their activity.

Similar to Hardy (2001), mean distances of bison and elk groups from groomed road segments during winter 2003 did not indicate avoidance of the road as motorized use increased (as indicated by daily over-the-snow vehicle traffic entering the West Entrance Station). In combination with the relatively minor and infrequent responses by wildlife to over-the-snow vehicle traffic, these results suggest that wildlife habituated to motorized winter use. Elk in the upper Madison River drainage study area are non-migratory due to the availability of year-round habitat (Craighead et al. 1973, Garrott et al. 2003). 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). 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) 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 winter 2003 was twice as high as during Aune's (1981) study. Despite this increased exposure to motorized winter use, bison and elk have continued to utilize the same core winter range during the past three decades. For the most part, over-the-snow vehicles 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. 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 reduce wildlife disturbance rates.

Despite this apparent habituation, any human activity in close proximity provoked behavioral responses from wildlife. Similar to Hardy (2001), we found an increase in behavioral responses by ungulate groups to motorized use as the distance from groomed roads decreased. In addition, Jaffe et al. (2002) reported that 17% of animals within 100 meters of the road (n = 17,209) responded to stopped over-the-snow vehicles, whereas only 3% of the 7,924 animals observed farther than 100 meters from the road (n = 297) visibly responded to the presence of over-the-snow vehicles. 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.

Ninety percent 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. Elk groups were observed using groomed roads less than bison. 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 over-the-snow vehicles 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 2003, we observed that snowmobile and snow coach groups impeded or hastened wildlife movement during 13 and 25 percent, respectively, of interactions when animal groups were on the groomed roads. Similar to Bjornlie and Garrott (2001), we occasionally observed animals being moved by over-the-snow vehicles along extended distances of groomed road 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 winter 2003.

During winter 2003, eleven animals were killed by snowmobiles (n = 7) and wheeled vehicles (n = 4). No animals were reported killed by snow coaches. 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 percent). 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 as follows: 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, despite the presence of wolves in the study area since 1996 (Hardy 2001, Jaffe 2001). These bison and elk winter in the same areas each year, despite detectable behavioral and stress hormone responses by individual animals to increased over-the-snow vehicle use since the late 1970's. In other words, these populations have coexisted with motorized winter use without a decline in abundance. Thus, any adverse effects of motorized winter use to ungulates have apparently been compensated for at the population level. 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.

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 problem. 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 human winter recreation may be more of an issue than the actual effects of such recreation to wildlife.

V. RECOMMENDATIONS

Monitoring results during winter 2003 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); and 3) reduce the number of stops to observe wildlife and human activities away from vehicles during these stops.

We will continue to evaluate data collected during previous and future years to refine these recommendations and identify other variables that are important for adaptive management of motorized winter use to minimize the frequency of possible disturbances to wildlife. As mentioned previously, Dr. John Borkowski, a statistician at Montana State University, is currently analyzing data collected during 1999-2003 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. These analyses should also enable us to develop a rigorous long-term monitoring plan that evaluates if human presence or activities have a detrimental effect on wildlife populations in Yellowstone National Park following the implementation of proposed management changes in human use during the winter of 2004.

We will also modify the data collection protocol during winter 2004 to improve the quality of data collected for future statistical analyses, while ensuring that these data can still be combined or compared with previously collected data. During 2003, we recorded the "predominant response behavior" of a wildlife group to a group of motorized winter vehicles. A large amount of information is lost using this classification system. Under ideal circumstances, observers would quantify the response of each animal in the group. This may be reasonable for a species in which group sizes are small. However, it is not feasible for large or even moderately sized groups where the simultaneous observation of every individual is impossible. Thus, we propose to gain partial additional information about the distribution of responses across multiple categories by recording the percentages of animals in the group that elicit each type of behavior.

By recording responses in this manner, we can determine if more active responses occurred when the predominant behavior was "no response." With this information, more informative models could also be developed to study the relationships between the proportion of a group that responded (e.g., either look/resume or more active responses) and other variables, such as number of over-the-snow vehicles, guided versus unguided groups, distance to road, and group size.

During winter 2003, we did not measure flight or movement distances of wildlife during each interaction. During winter 2004, we will estimate the frequency of movements and maximum distances moved by wildlife during each interaction. These data will be used in conjunction with estimates of total daily energy expenditure and energy expended during various types of behaviors by elk (coalesced from the literature) to develop gross estimates of energy loss due to disturbances in relation to total daily energy expenditure.

Likewise, during winter 2003 observers recorded the highest level of human activity (i.e., the most potential for disturbance) during observations of human/wildlife interactions. To improve the quality of the human response variable for modeling purposes during 2004, we will implement modifications similar to those stated for the wildlife response variable. Specifically, we will: 1) record the number of people who dismount their motorized vehicles; 2) provide the number of vehicles/humans for each of the seven human response categories; 3) record the actual number of seconds that over-the-snow vehicles stop to observe wildlife, rather than categorizing the response as "stop-resume" or "wait."

To determine if the percentages of wildlife responses to human winter activities has truly changed (either increased or decreased), it is important to have baseline levels established. Thus, we need "control" estimates of the percentages of wildlife responses in the absence of human activities (e.g., how often do elk or bison exhibit a look-and-resume response when there are no interactions with motorized vehicles). Otherwise, we can not determine if observed response rates by wildlife during interactions with motorized vehicles are relatively high or low. For example, suppose there is 91% "no response" and a 9% "look-and-resume" response from bison during recorded human/wildlife interactions. From these estimates, we cannot determine if 9% look-and-resume response rate can be considered high or low. However, if we had control group data that indicated a 98% "no response" rate and a 2% "look-and-resume" response rate for bison, then we would have evidence indicating an increased look-and-resume response rate given a human/wildlife interaction. Alternatively, if we had control group data that indicated a 90% "no response" rate and a 10% "look-and-resume" response rate for bison, then we would have evidence indicating that the 9% look-and-resume response rate from the human/wildlife interaction data is not unusual relative to periods when motorized vehicles are absent.

To establish these baseline estimates of wildlife behaviors, we will conduct scans of wildlife behavior at 5-minute intervals during time periods prior to interactions with motorized vehicle groups. Wildlife behaviors will be recorded using the same six wildlife response categories as during interactions motorized vehicles. Observers will record scans at 5-minute intervals from the time they spot the wildlife group until the first indication of the arrival of motorized vehicles (e.g. by sight or sound), or until the observers leave because no human/wildlife interactions occurred.

During 2003, we obtained small sample sizes of interactions between motorized vehicles and bald eagles and coyotes. Additional data will be required to adequately model the responses of these species with a generalized logits regression model. Thus, we will continue collecting data on these species for at least one or more seasons so that these data can be rigorously analyzed using statistical techniques.

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Appendix A: Brief summary of studies regarding wildlife responses to motorized winter use in Yellowstone National Park during 1981 to 2002.

Aune (1981) studied winter recreation and effects on wildlife in the upper Madison River drainage of Yellowstone. He documented instances of visitors impeding wildlife travel, and found that animals were displaced from habitat near roads and trails. These observations were infrequent and Aune (1981) reported that animals habituated to disturbance after two weeks of exposure. The study concluded that wildlife distribution and survival were not adversely affected by winter visitation.

Bjornlie and Garrott (2001) studied bison ecology and use of road corridors in the Madison, Gibbon, and Firehole drainages of Yellowstone National Park during 1998 and 1999. Road grooming facilitates over-the-snow vehicle use and winter recreation, but has been hypothesized to effect bison movements. Bjornlie and Garrott (2001) made 28,293 observations of bison groups and compared bison travel and migration patterns to the distribution of groomed roads. The study found bison road use was negatively correlated with grooming, with a peak of bison road use in April and lowest use during the period of road grooming operations.

Cassirer (1992) studied the responses of adult female elk to disturbance by cross-country skiers in the Mammoth, Lamar, and Stephen's Creek areas of Yellowstone National Park during 1987 and 1988. The median distance at which elk in undeveloped areas started to move when skiers approached was 400 meters (range = 125-1,700 meters). After being disturbed, elk moved uphill, to steeper slopes, away from the road, and closer to trees. Elk responses did not seem to be affected by the total number of skiers or frequency of skier groups. No evidence of elk habituation or avoidance was associated with repeated disturbances by skiers during the study. Displacement of elk was usually temporary and elk returned after skiers left the area. Cassirer (1992) recommended concentrating skier activity in small areas with abundant topographic relief that were at least 650 meters from elk wintering areas.

Hardy (2001) studied elk and bison behavioral responses to winter recreation in the upper Madison River drainage of Yellowstone National Park during the winters of 1999 and 2000. She observed 885 elk groups and 1,812 bison groups during surveys of groomed road segments and off-road trails. Hardy (2001) reported that behavioral responses of ungulates increased as distance between human activities decreased.

Animal Response

Species	No.	No Response	Look-Resume	Alarm/ Attention	Amble	Flight
Bison	1812	1655	131	3	7	16
Elk	885	550	260	37	23	15

Additionally, Hardy (2001) reported stress hormone levels in elk residing along an intensively traveled road segment compared to elk residing along a less-traveled segment. Hardy (2001) reported a general correlation between increased stress hormone levels in elk and increased numbers of over-the-snow vehicles entering the West gate. However, she also reported that the probability that either bison or elk would respond to over-the-snow vehicles decreased as numbers of over-the-snow vehicles increased. This result suggested that the predictability and frequency of traffic promoted habituation by elk and bison, even though this habituation effect could not be detected in stress hormone levels.

Reinertson et al. (2002) monitored bison road use during winters between 1997-2002. They recorded 13,845 observations of bison locations and travel patterns (approximated by tracks) in relation to groomed road surfaces. Reinertson et al. (2002) supported the findings of Aune (1981) and Bjornlie and Garrott (2001) that bison use of groomed roads was minimal. However, Reinertson et al. (2002) cautioned that road use by bison was highly variable and that a 5-year study was not sufficient to make management decisions. In addition, an intensive monitoring project was conducted in the Hayden Valley area of Yellowstone National Park to collect quantitative data of bison use of groomed road segments, during the 1997-98, 1998-99, 1999-00, 2000-01, and 2001-02 winter seasons. An identical project was also conducted in the Mammoth to Gibbon Falls area during the 1998-99, 1999-00, 2000-01, and 2001-02 winters. A third study area was added during the 2000-01 winter in the Madison area and continued during the 2001-02 winter season. Random crepuscular and daytime ground surveys, automated photo point data, and groomer operator bison observations were collected in an effort to quantify and compare bison use of groomed roads to snow depth, habitat, time of day, and winter weather conditions. Aerial surveys were also used to monitor bison movements and distribution within the study areas. Sixty-four to 68 ground surveys were completed between December and March in each study area during each study period (Hayden 1997-98, 1998-99, 1999-00, 2000-01, 2001-02; Mammoth 1998-99, 1999-00, 2000-01, 2001-02; Madison 2000-01, 2001-02). A total of 6,581 bison group observations were recorded during these periods in Hayden, 3,467 in Mammoth, and 920 in Madison. Group sizes ranged from 1-463 in the Hayden study area, 1-207 in the Mammoth study area, and 1-346 in the Madison study area. Groups averaged approximately 20.2, 12, and 29 individuals respectively. Bison distances from the road ranged from 0-3.8 kilometers. Of the 6,581 observations in the Hayden study area, 7.9% (519) were documented on the roads. A lesser amount, 7.2% (251) of the 3,467 observations in the Mammoth study area were documented on the roads. During the first two years of study, 12.8% (118) of the 920 observations in the Madison study area were documented on the roads. A large majority, 818 (79.6%) of the 1027 bison groups observed traveling were on or within 25m of the road surface. A minimum of fifteen groups totaling 196 individuals have been documented leaving the northern section of the Mammoth study area, during the 1998-99, 1999-00, 2000-01, and 2001-02 study periods. Additional surveys were completed during the month of April in each study area during the 2000-01 and 2001-02 study periods. Road use nearly doubled during the April study periods increasing from 8.1% to 14.9%. Photo data showed a total of 17.7% of bison observations were of bison on roads, while a total of 13.6% of groomer runs recorded bison on the road. Aerial survey results indicated that the number of bison remained fairly stable in the three study areas between December and February. Bison numbers changed substantially however during the month of March, increasing in the Mammoth study area and decreasing in the Hayden study area. In the Madison study area, the numbers remained stable during March. We encourage more years of data collection to help determine how bison use winter roads in Yellowstone National Park on a larger temporal scale. Moreover, we need to capture a major snow year to help understand how the dynamics of bison and park winter roads work.

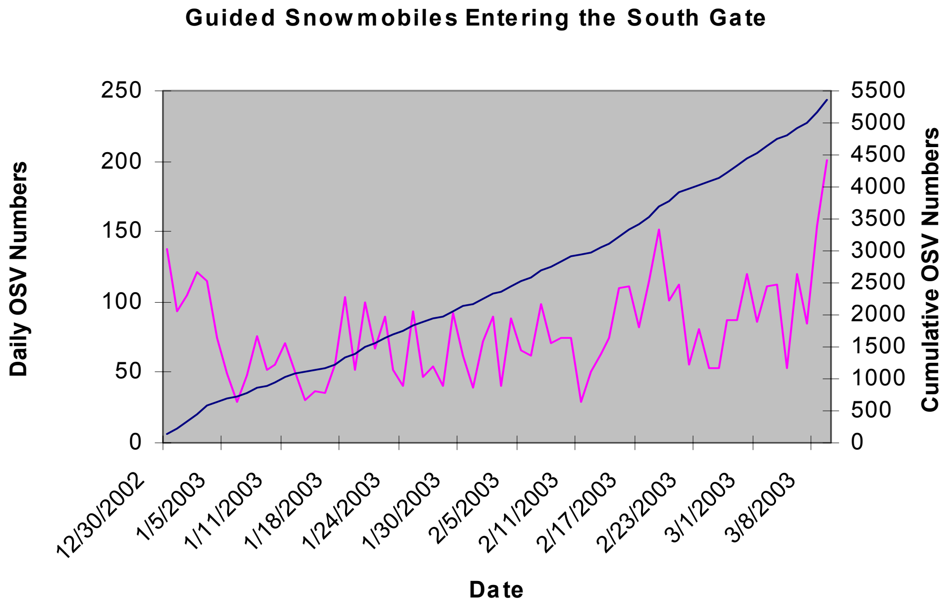
Jaffe et al. (2002) studied responses of wildlife to over-the-snow vehicle traffic and human behavior along road segments in the Madison and Firehole River drainages of Yellowstone National Park during the winter of 2001-2002. These authors observed 25,173 animals during surveys of road segments, 87% of which exhibited no detectable response to over-the-snow vehicles. Sixty-eight percent of the animals that exhibited a detectable response merely looked at the over-the-snow vehicles and associated humans and resumed their activity. The remainder of the responses were more active, including walk/swim away, rise from bed, attention/alarm, flight, agitate, jump snow berm, and charge. In addition, Jaffe et al. (2002) categorized animals as being less than, or greater than, 100 meters from the road to determine if distance caused differing reactions to the presence of over-the-snow vehicles and associated humans. Seventeen percent of animals within 100 meters of the road (n = 17,209) responded to stopped over-the-snow vehicles. Only three percent of the 7,924 animals observed farther than 100 meters from the road (n = 297) visibly responded to the presence of over-the-snow vehicles.

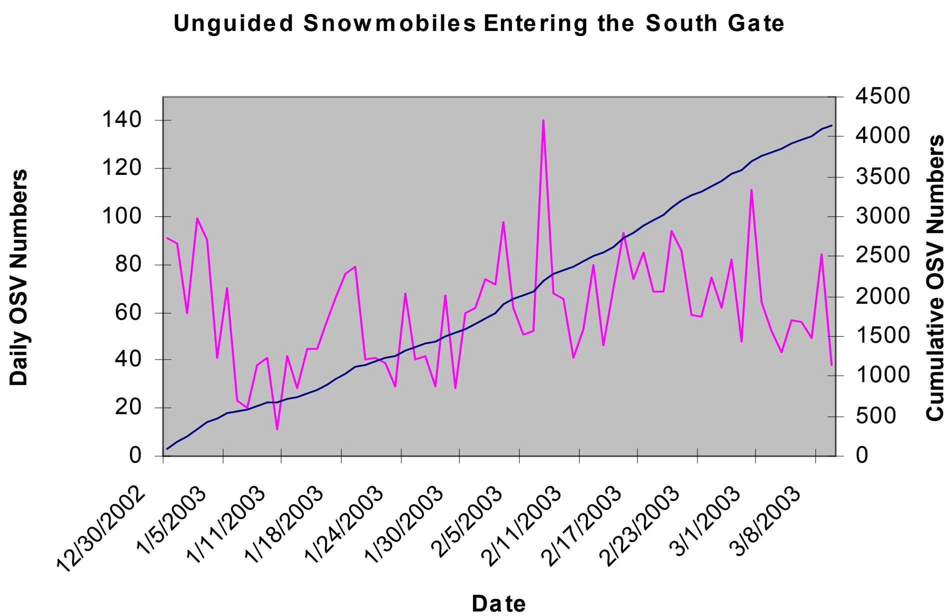
Animal responses during wildlife-human interactions while animals were off-road (Jaffe et al. 2002). Categories of response behaviors were "No Response" (no apparent response), "Look-Resume", "Moderate Response" (e.g., walk/swim away, rise from bed, attention/alarm), and "Agitation" (e.g., flight, buck, kick, bison tail-raise, jump snow berm, and charge). Percent of Look-Resume reported (in parentheses) is of the total animal responses.

		Animal Response				
Species	**No.**	**No Response (%)**	**Look-Resume (%)**	**Moderate Response**	**Agitation**	**Total Responding (%)**
Bison	2,000	1,887 (94)	77 (68)	32 (28)	4 (4)	113 (5)
Elk	489	337 (69)	109 (72)	33 (22)	10 (7)	152 (31)
Swans	448	353 (79)	52 (55)	43 (45)	0	95 (21)
Bald Eagles	21	15 (71)	4 (67)	0	2 (33)	6 (29)
Coyotes	5	2 (40)	2 (67)	0	1 (33)	3 (60)
Total	2,963	2,594 (88%)	244 (66%)	108 (29%)	17 (5%)	369 (12%)

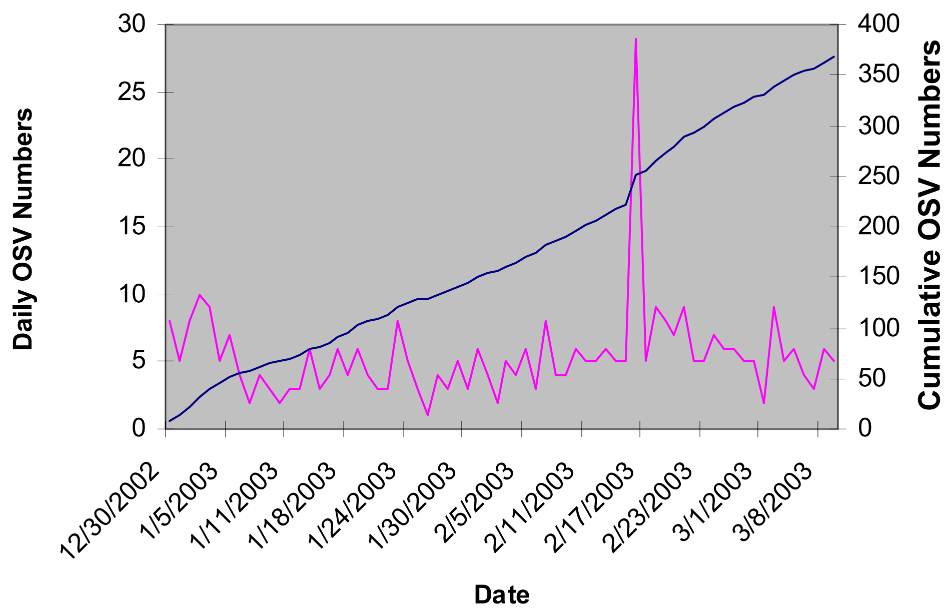
Appendix B: Daily and cumulative numbers of commercially guided snowmobiles, unguided snowmobiles, snow coaches, and all types of over-the-snow vehicles (OSVs) entering various entrance stations of Yellowstone National Park during winter 2002-03. Daily totals are displayed on the left axis, while the winter's cumulative total is displayed on the right axis. Note that the scales of the Y axes vary among figures.

South Entrance Station

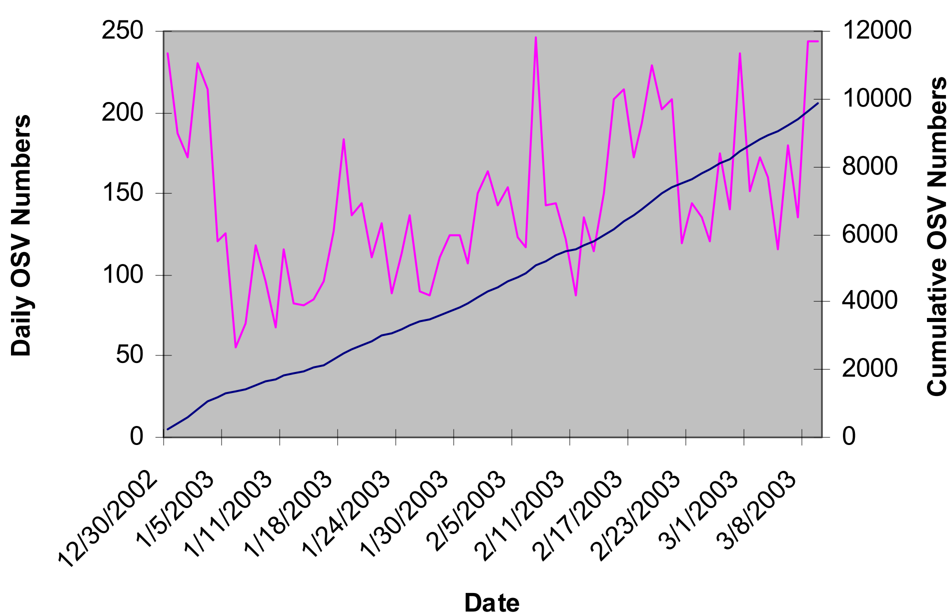




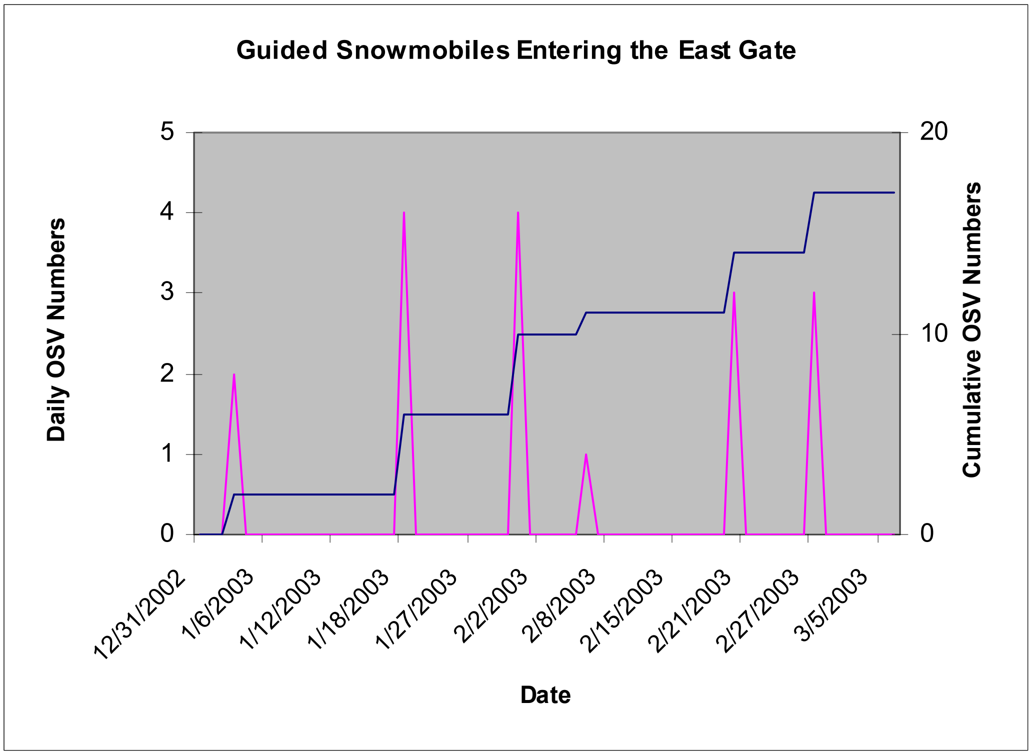
Snowcoaches Entering the South Gate

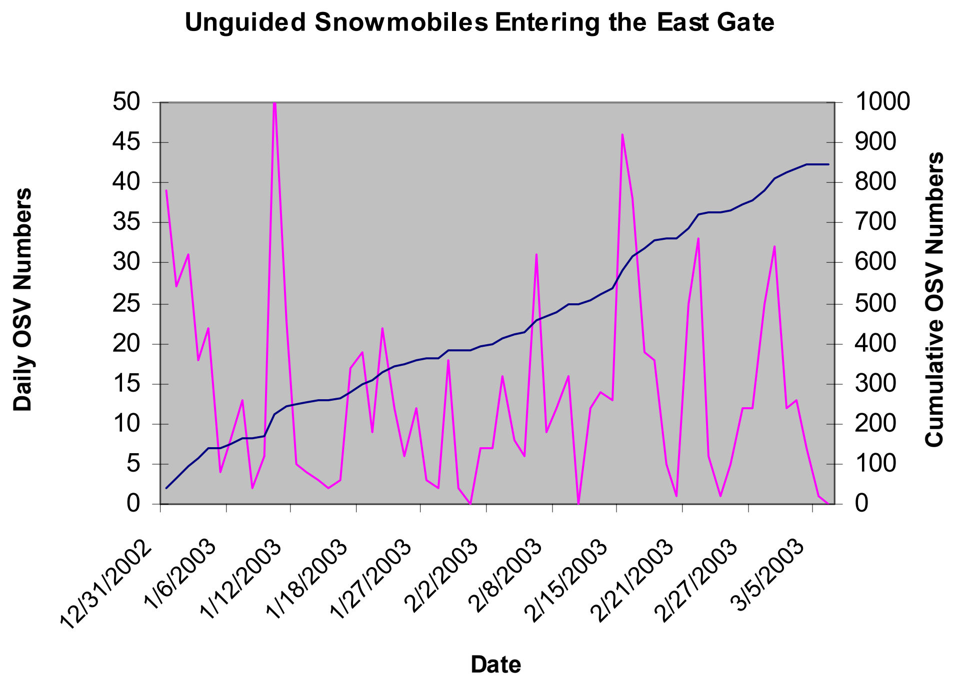


All Types of OSVs (Combined) Entering the South Gate

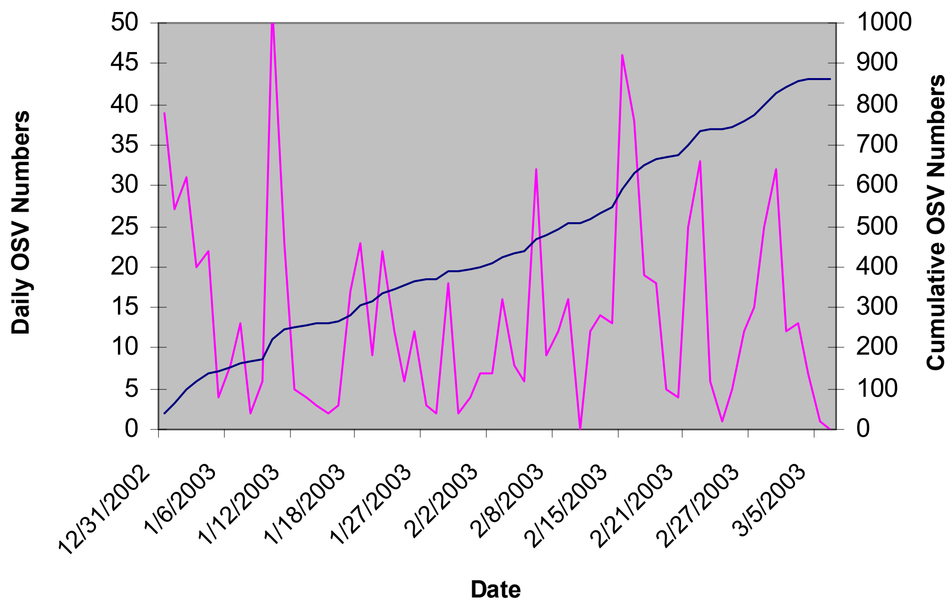


East Entrance Station



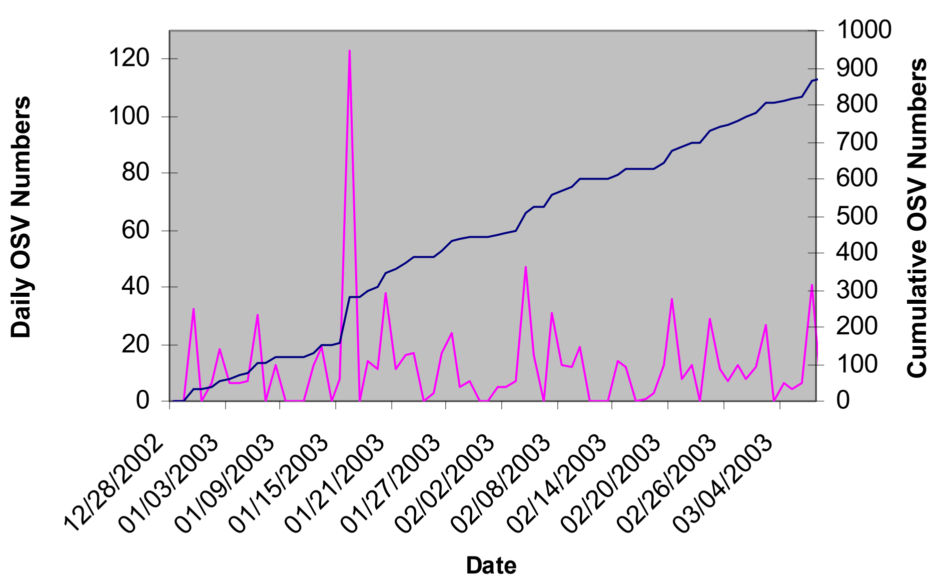


All Types of OSVs (Combined) Entering the East Gate

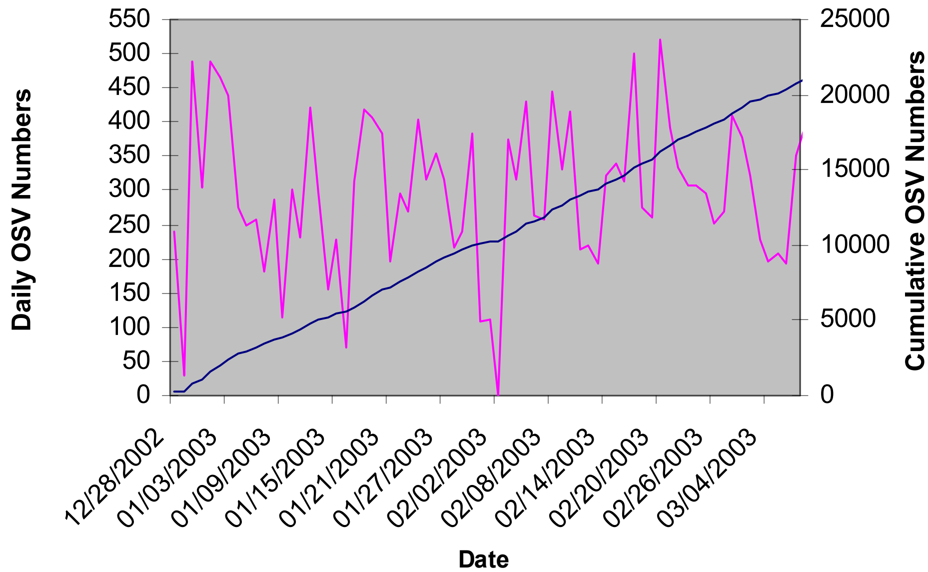


West Entrance Station

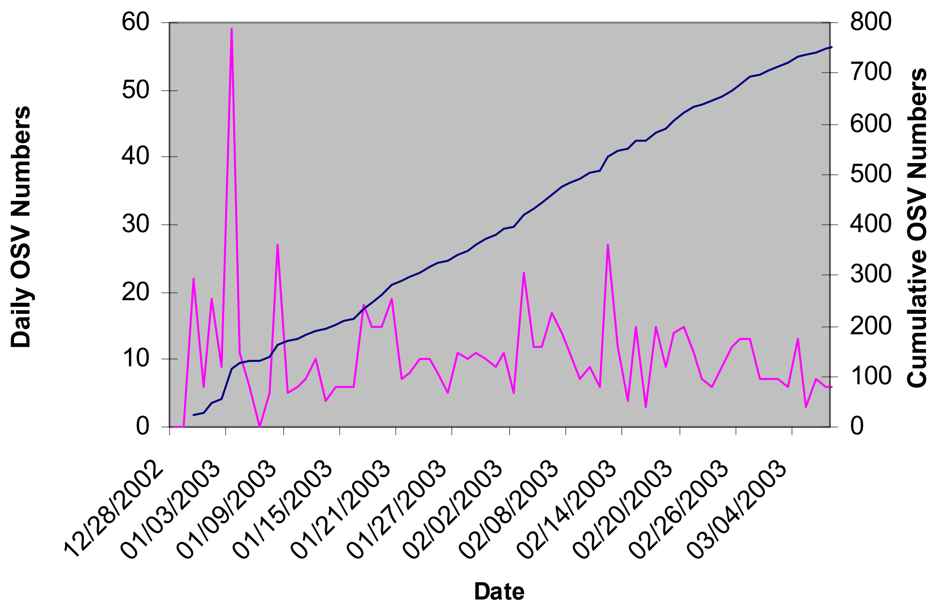
Guided Snowmobiles Entering the West Gate



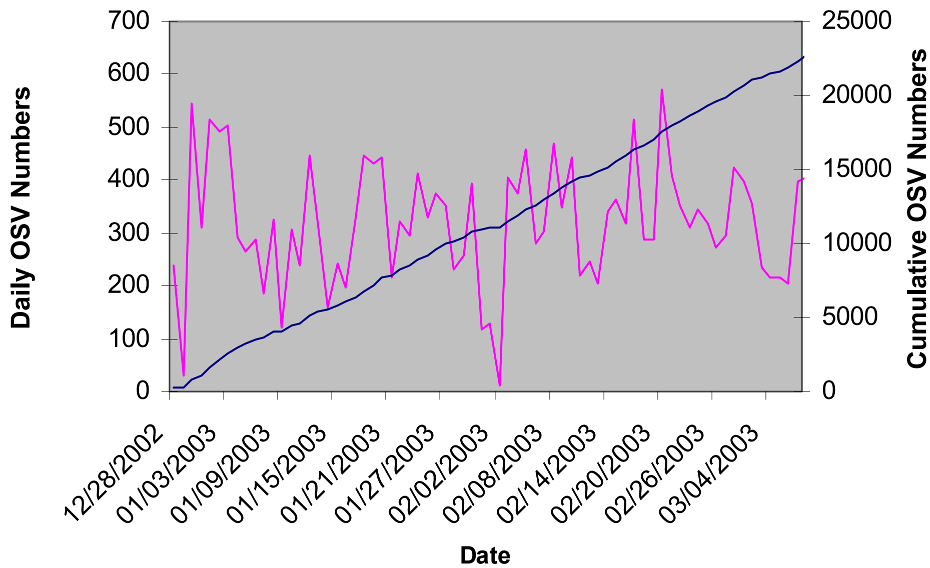
Unguided Snowmobiles Entering the West Gate



Snowcoaches Entering the West Gate



All Types of OSVs (Combined) Entering the West Gate



Appendix C: Budget for monitoring the potential effects of motorized use on wildlife during winter 2002-03, Yellowstone National Park, Wyoming.

Expenditures	Unit Cost	Total Cost	Organization
Personnel Services			
Temp NTE 1039 hr GS-6 Biotech	$1,200/PP @ 12PP (PP26-PP11) @ 1 person	$14,400	YCR
Temp NTE 1039 hr GS-5 Biotech	$1,000/PP @ 10PP (PP26-PP9) @ 5 persons	$55,000	CRO ($40,000) / YCR
Volunteer	$150/PP @ 10PP (PP26-PP9) @ 1 person	$ 1,500	YCR
Volunteer housing	$100/PP @ 10PP (PP26-PP9) @ 1 person	$ 1,000	YCR
Premium	OT and differential	$ 3,500	CRO (70%) / YCR (30%)
Clerical support		$ 3,000	CRO (70%) / YCR (30%)
Supplies and Equipment			
Palm M500 Hand-held Computer	6 computers @ $300 each	$ 1,800	YCR
RACAL radios, battery packs, and battery chargers	2 packages @ $2,500 each	$ 5,000	YCR
Miscellaneous equipment (GPS, binoculars, etc.)		$ 5,000	YCR
Computer software, books, manuals		$ 1,800	YCR
Contractors and Cooperators			
Biostatistician: data analyses and sampling design	Dr. John Borkowski, Montana State University	$15,000	YCR
Swan aerial flights	1 flight/month for 5 months @ $800/flight (5 hr @ $160/hr)	$ 4,000	YCR
Fecal glucocorticoid assays	Dr. Scott Creel, Montana State University	$ 4,000	YCR
Wolf aerial monitoring	30 hrs flight @ $160/hr	$ 4,000	YCR
Ungulate abundance estimates and fecal collection	Dr. Robert Garrott, Montana State University	$ 4,000	YCR
Fuel for elk and bison monitoring	Dr. Robert Garrott, Montana State University, 1,400 gallons @ $1.40/gallon	$ 2,000	YCR
Total		**$125,000**	

Appendix D. Summaries of observed wildlife groups and interactions by road segment and survey crew during December 26, 2002, through April 18, 2003, Yellowstone National Park, Wyoming.

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

Road Segment	Species	Groups Observed	Interactions
Madison-Old Faithful	Bison	675	599
	Elk	203	192
	Swans	33	31
	Coyote	15	9
	Bald Eagle	56	31
	Wolf	1	1
	Sandhill Crane	1	0
Madison-West Yellowstone	Bison	232	228
	Elk	198	195
	Swans	140	138
	Coyote	18	16
	Bald Eagle	97	64
	Golden Eagle	5	3
	Hawk	2	1
	Sandhill Crane	1	0
	GB Heron	3	0
	Muskrat	1	0
Canyon to Norris	Bison	20	16
	Elk	2	2
	Swans	0	0
	Coyote	3	1
Madison to Norris	Bison	113	85
	Elk	12	11

	Swans	7	7
	Coyote	8	5
	Bald Eagle	19	12
	Wolf	3	3
Mammoth to Norris	Bison	74	50
	Elk	9	6
	Swans	0	0
	Coyote	7	6
	Bald Eagle	2	0
	Golden Eagle	1	1
	Wolf	1	1
Mammoth to Lamar Valley	Bison	621	389
	Elk	484	191
	Swans	4	2
	Coyote	102	68
	Wolf	46	20
	Bald Eagle	30	13
	Pronghorn	11	4
	Golden Eagle	19	4
	Sheep	11	10
	Goat	3	2
	Beaver	1	0
	Moose	4	3
Canyon to Lake Butte	Bison	498	300
	Elk	0	0
	Swans	255	167
	Coyote	62	41
	Otter	4	1
	Bald Eagle	66	28

	Golden Eagle	1	0
	Wolf	2	1
West Thumb to Fishing Bridge	Bison	55	41
	Elk	0	0
	Swans	5	5
	Coyote	7	7
	Otter	1	1
	Bald Eagle	3	1
	Golden Eagle	1	0
	Wolf	1	1
Fishing Bridge to Silvan Pass*	Bison	6	4
	Elk	0	0
	Swans	3	1
	Coyote	1	1

* - Discontinued route

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	697	16	645	21
Madison to Old Faithful	984	23	863	29
Mammoth to Norris	94	2	64	2
Norris to Madison	162	4	123	4
Mammoth to the upper Lamar Valley	1336	31	706	23
Canyon Village to Norris	25	1	19	1
Fishing Bridge to West Thumb	73	2	56	2
Canyon Village to Lake Butte	888	21	538	18
Fishing Bridge to Sylvan Pass*	10	0.2	6	0.2

* - Discontinued route

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

Area	Observations	% of Total Observations	Interactions	% of Total Interactions
Madison	1681	39.4	1508	49.9
Mammoth	1592	37.3	893	29.6
Canyon	996	23.3	619	20.5

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	1681	89.7
Mammoth	1592	56.1
Canyon	996	62.1

Appendix E. Comparison of human behavior during interactions with wildlife (i.e., bison, elk, trumpeter swans) among over-the-snow vehicles in commercially guided groups (including snowmobiles and snow coaches), unguided groups of snowmobiles, wheeled vehicles, and administrative groups (i.e., park and concessionaire staff) during December 26, 2002, through April 18, 2003, Yellowstone National Park, Wyoming. The dataset contains small numbers of observations in which human behavior was not visible or recorded as 'unknown'; these unknown responses are not included in the appendix.

Snow Coach Users in High-Use Areas (i.e., Madison to Old Faithful, Madison to West Yellowstone, and Canyon to Lake Butte).

Elk

Human Behavior	Number of Events	Proportion
None	17	59%
Stop-Resume	2	7%
Watch	4	14%
Dismount	1	3%
Approach	5	17%

Bison

Human Behavior	Number of Events	Proportion
None	33	51%
Stop-Resume	3	5%
Watch	11	17%
Dismount	3	5%
Approach	9	14%
Impede-Hasten	5	8%

Swans

Human Behavior	Number of Events	Proportion
None	11	46%
Watch	4	16.5%
Dismount	4	16.5%
Approach	5	21%

Snow Coach Users in Low-Use Areas (i.e., Norris to Mammoth, Norris to Madison and West Thumb to Fishing Bridge, and Canyon to Norris)

Bison

Human Behavior	Number of Events	Proportion
None	14	50%
Stop-Resume	4	14%
Watch	5	18%
Dismount	4	14%
Impede-Hasten	1	4%

Swans

Human Behavior	Number of Events	Proportion
None	2	100%

Snowmobile Users in High-Use Areas (i.e., Madison to Old Faithful, Madison to West Yellowstone, and Canyon to Lake Butte).

Elk

Human Behavior	Commercially Guided Groups		Unguided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion	No. Events	Proportion
None	5	38	74	52	9	50
Stop-Resume			2	1		
Watch	1	8	15	11	4	22
Dismount	1	8	20	14	5	28
Approach	6	46	30	21		
Impede-Hasten			1	1		

Bison

Human Behavior	Commercially Guided Groups		Unguided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion	No. Events	Proportion
None	11	55	305	64	21	24
Stop-Resume			20	4	7	8
Watch	1	5	45	9	47	53
Dismount	4	20	66	14	13	15
Approach	4	20	30	6		
Impede-Hasten			12	3		

Swans

Human Behavior	Commercially Guided Groups		Unguided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion	No. Events	Proportion
None	10	71	166	77	3	21
Stop-Resume			10	5		
Watch	1	7	12	6	4	29
Dismount			20	9	7	50
Approach	3	21	7	3		

Snowmobile Users in Low-Use Areas (i.e., Norris to Mammoth, Norris to Madison and West Thumb to Fishing Bridge, and Canyon to Norris)

Elk

Human Behavior	Commercially Guided Groups		Unguided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion	No. Events	Proportion
None			7	58		
Stop-Resume			3	25		
Watch						
Dismount			2	17		

Bison

Human Behavior	Commercially Guided Groups		Unguided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion	No. Events	Proportion
None	5	56	62	57	1	50
Stop-Resume	3	33	14	13		
Watch			15	14	1	50
Dismount	1	11	14	13		
Approach			3	3		

Swans

Human Behavior	Commercially Guided Groups		Unguided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion	No. Events	Proportion
None	2	100	3	37		
Stop-Resume			1	12		
Watch			2	25		
Dismount			2	25		

Wheeled Vehicle Areas (i.e., winter use on the plowed road from Mammoth to Pebble Creek; note: administrative use of all road segments in the spring is also included in this dataset).

Elk

Human Behavior	Commercially Guided Groups		Unguided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion	No. Events	Proportion
None	4	40	131	69	95	52
Stop-Resume	1	10	17	9	3	2
Watch	2	20	15	8	79	44
Dismount	3	30	19	10	3	2
Approach			7	4	1	1

Bison

Human Behavior	Commercially Guided Groups		Unguided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion	No. Events	Proportion
None	10	77	347	80	196	43
Stop-Resume			19	4	17	3
Watch	1	8	34	8	238	53
Dismount			29	7	2	1
Approach	2	15	3	1		

Swans

Human Behavior	Commercially Guided Groups		Unguided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion	No. Events	Proportion
None	3	38	7	88	1	2
Stop-Resume					8	16
Watch	3	38			41	80
Dismount	1	13	1	13	1	2
Approach	1	13				

F. Comparison of wildlife (i.e., bison, elk, swans) responses during interactions with over-the-snow vehicles in commercially guided groups (including snowmobiles and snow coaches), unguided groups of snowmobiles, wheeled vehicles, and administrative groups (i.e., park and concessionaire staff) during December 26, 2002, through April 18, 2003, Yellowstone National Park, Wyoming. The dataset contains small numbers of observations in which wildlife responses were not visible or recorded as 'unknown'; these unknown responses are not included in the appendix.

Wildlife Responses to Snowmobile Users in High-Use Areas (i.e., Madison to Old Faithful, Madison to West Yellowstone, and Canyon to Lake Butte).

Elk

Wildlife Response	Commercially Guided Groups		Unguided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion	No. Events	Proportion
None	5	42	43	31	6	33
Look-Resume	5	42	62	45	8	44
Travel	1	8	9	6	2	11
Alarm-Attention	1	8	23	17	2	11
Flight			2	1		

Bison

Wildlife Response	Commercially Guided Groups		Unguided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion	No. Events	Proportion
None	12	60	346	73	58	66
Look-Resume	5	25	83	17	17	19
Travel	2	10	23	5	9	10
Alarm-Attention	1	5	12	3	3	3
Flight			12	3	1	1
Defense			1	2		

Swans

Wildlife Response	Commercially Guided Groups		Unguided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion	No. Events	Proportion
None	10	71	117	54	4	29
Look-Resume	2	14	64	30	5	36
Travel	2	14	27	13	3	21
Alarm-Attention			4	2	2	14
Flight			3	1		

Wildlife Responses to Snowmobile Users in Low-Use Areas (i.e., Norris to Mammoth, Norris to Madison and West Thumb to Fishing Bridge, Canyon to Norris and Canyon to Fishing Bridge)

Elk

Wildlife Response	Commercially Guided Groups		Unguided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion	No. Events	Proportion
None			8	67		
Look-Resume			4	33		

Bison

Wildlife Response	Commercially Guided Groups		Unguided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion	No. Events	Proportion
None	6	67	89	82	1	
Look-Resume	3	33	6	6	1	
Travel			6	6		
Alarm-Attention			7	6		

Swans

Wildlife Response	Commercially Guided Groups		Unguided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion	No. Events	Proportion
None	2	100	3	38		
Look-Resume			1	13		
Travel			4	50		

Wildlife Responses to Snow Coach Users in High-Use Areas (i.e., Madison to Old Faithful, Madison to West Yellowstone, and Canyon to Lake Butte).

Elk

Wildlife Response	Number of Events	Proportion
None	6	21%
Look-Resume	9	32%
Travel	6	21%
Alarm-Attention	7	25%

Bison

Wildlife Response	Number of Events	Proportion
None	43	67%
Look-Resume	10	16%
Travel	4	6%
Alarm-Attention	5	8%
Flight	2	3%

Swans

Wildlife Response	Number of Events	Proportion
None	10	42%
Look-Resume	4	17%
Travel	6	25%
Alarm-Attention	2	8%
Flight	2	8%

Wildlife Responses to Snow Coach Users in Low-Use Areas (i.e., Norris to Mammoth, Norris to Madison and West Thumb to Fishing Bridge, Canyon to Norris and Canyon to Fishing Bridge)

Bison

Wildlife Response	Number of Events	Proportion
None	18	64%
Look-Resume	4	14%
Travel	3	11%
Alarm-Attention	3	11%

Swans

Wildlife Response	Number of Events	Proportion
None	2	100%

Wildlife Responses to Wheeled Vehicles (i.e., plowed road from Mammoth to Pebble Creek; note: administrative use in the spring 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	6	67	131	69	18	10
Look-Resume	2	22	40	21	82	45
Travel	1	11	15	8	26	14
Alarm-Attention			2	1	50	28
Flight			1	1	5	3

Bison

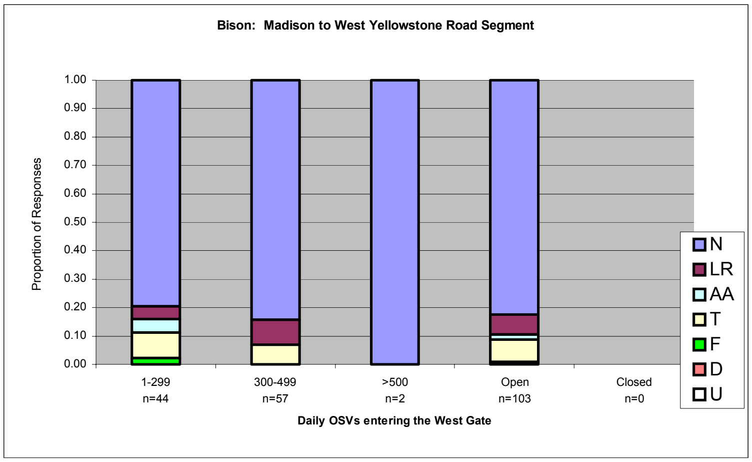
Wildlife Response	Commercially Guided Groups		Unguided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion	No. Events	Proportion
None	11	85	404	93	330	73
Look-Resume	2	15	17	4	82	18
Travel			7	2	26	6
Alarm-Attention			3	1	9	2
Flight			1	0	6	1

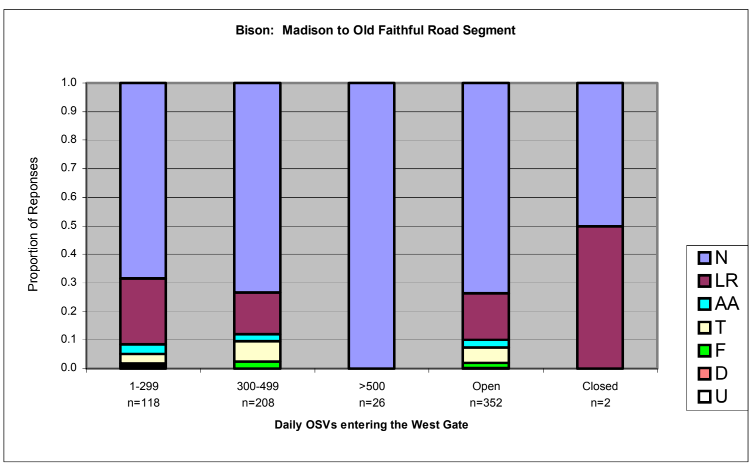
Swans

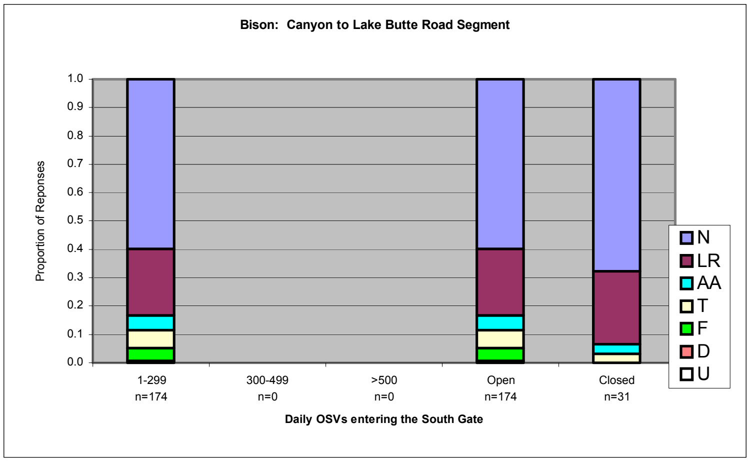
Wildlife Response	Commercially Guided Groups		Unguided Groups		Administrative Groups	
	No. Events	Proportion	No. Events	Proportion	No. Events	Proportion
None	3	38	6	75	42	82
Look-Resume	3	38	1	13	1	2
Travel	2	25	1	13	6	12
Alarm-Attention					2	4

Appendix G: Bison, elk, and trumpeter swan responses to motorized winter use along various road segments compared to daily numbers of over-the-snow vehicles entering the West Entrance Station, Yellowstone National Park, Wyoming, during winter 2002-03. Response categories are as follows: no apparent response ("N"); look-resume ("LR"); alarm-attention ("AA"); travel ("T"); flight ("F"); defense ("D"); and unknown ("U").

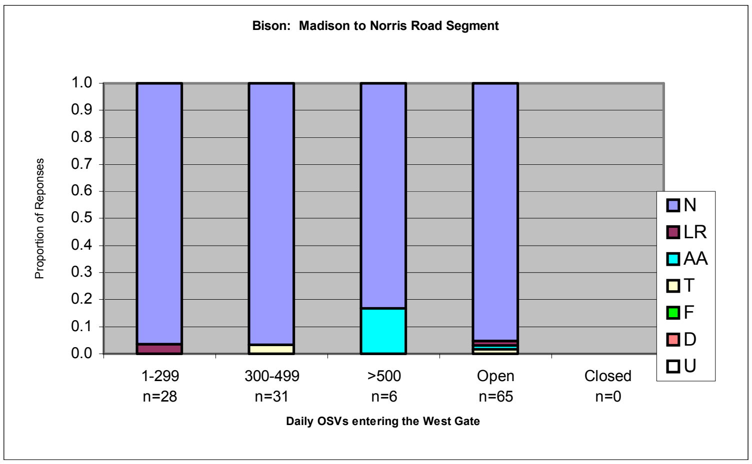
Bison



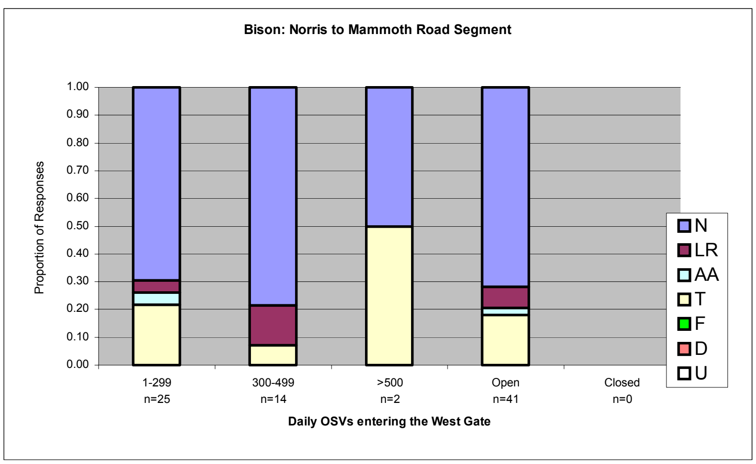




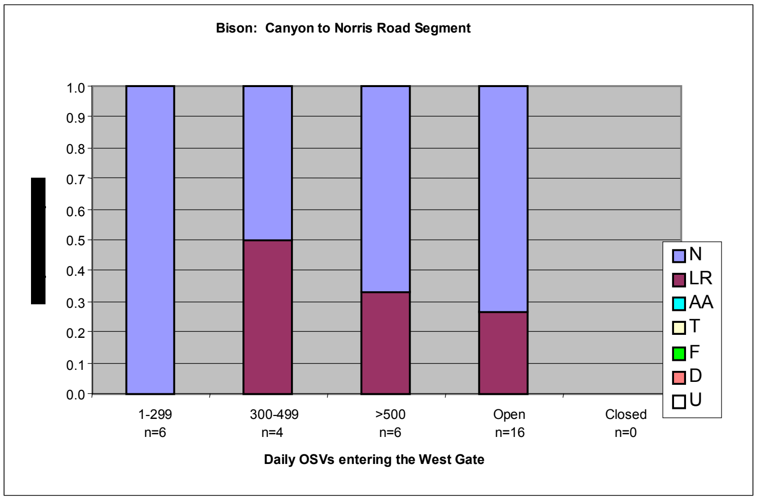
Bison: Canyon to Lake Butte Road Segment
Proportion of Reponses
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1-299 n=174
300-499 n=0
>500 n=0
Open n=174
Closed n=31
Daily OSVs entering the South Gate
N
LR
AA
T
F
D
U

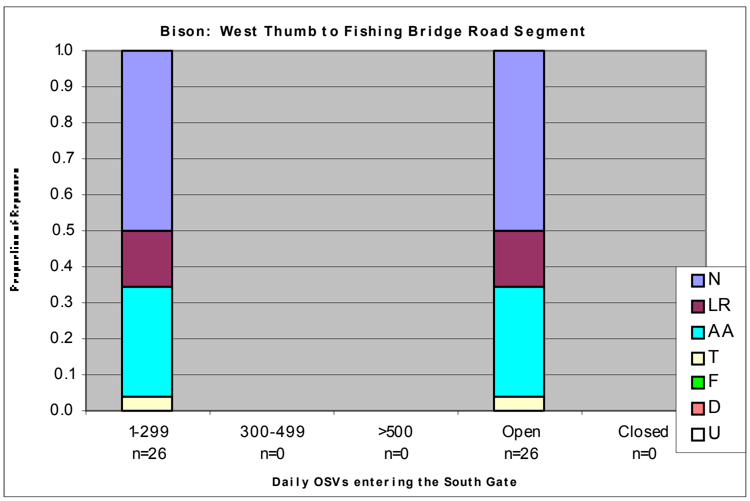


Bison: Madison to Norris Road Segment
Proportion of Reponses
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1-299 n=28
300-499 n=31
>500 n=6
Open n=65
Closed n=0
Daily OSVs entering the West Gate
N
LR
AA
T
F
D
U

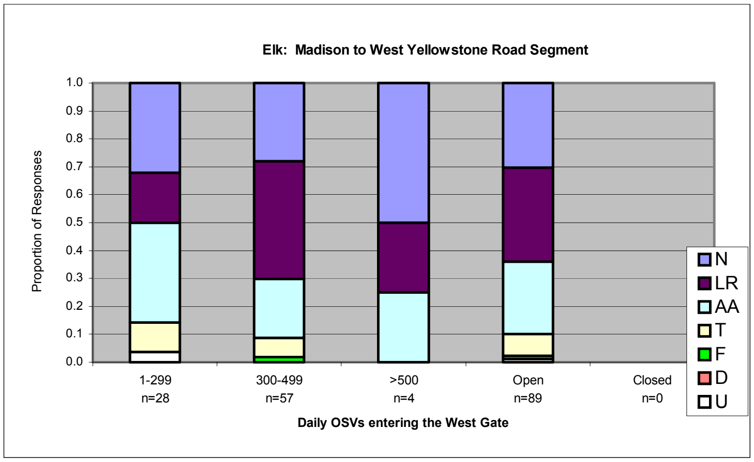


Bison: Norris to Mammoth Road Segment
Proportion of Responses
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1-299 n=25
300-499 n=14
>500 n=2
Open n=41
Closed n=0
Daily OSVs entering the West Gate
N
LR
AA
T
F
D
U

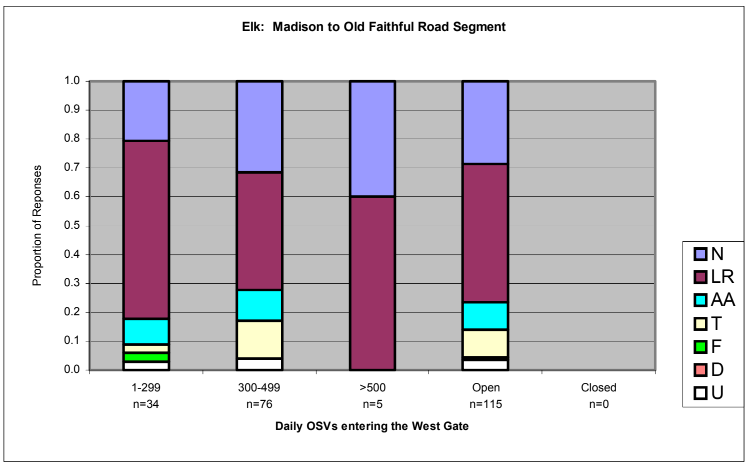

Bison: Canyon to Norris Road Segment
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1-299
n=6
300-499
n=4
>500
n=6
Open
n=16
Closed
n=0
Daily OSVs entering the West Gate
N
LR
AA
T
F
D
U


Bison: West Thumb to Fishing Bridge Road Segment
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1-299
n=26
300-499
n=0
>500
n=0
Open
n=26
Closed
n=0
Daily OSVs entering the South Gate
N
LR
AA
T
F
D
U

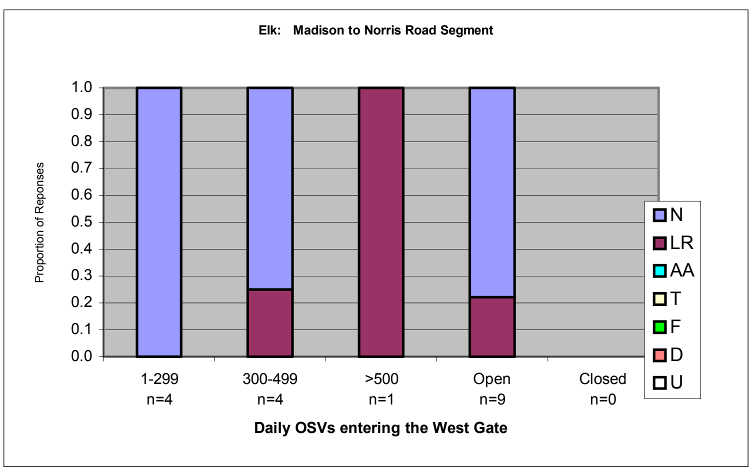
Elk



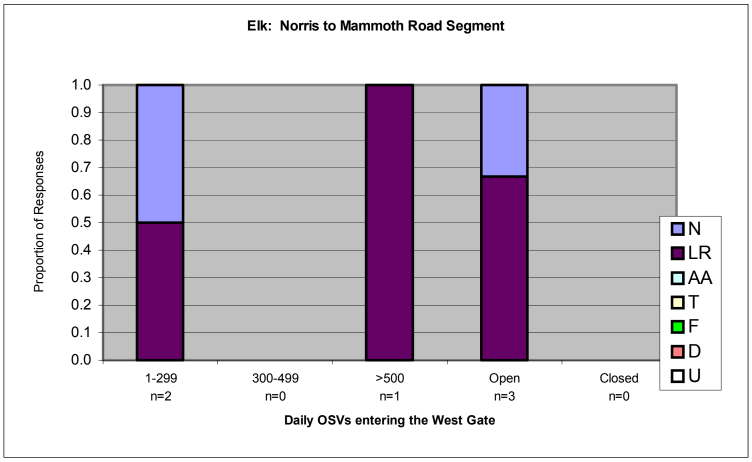
Elk: Madison to West Yellowstone Road Segment
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Proportion of Responses
1-299
n=28
300-499
n=57
>500
n=4
Open
n=89
Closed
n=0
Daily OSVs entering the West Gate
N
LR
AA
T
F
D
U



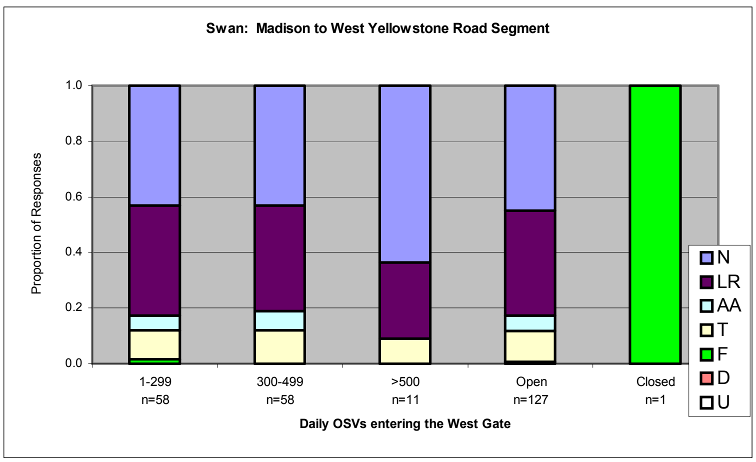
Elk: Madison to Old Faithful Road Segment
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Proportion of Reponses
1-299
n=34
300-499
n=76
>500
n=5
Open
n=115
Closed
n=0
Daily OSVs entering the West Gate
N
LR
AA
T
F
D
U

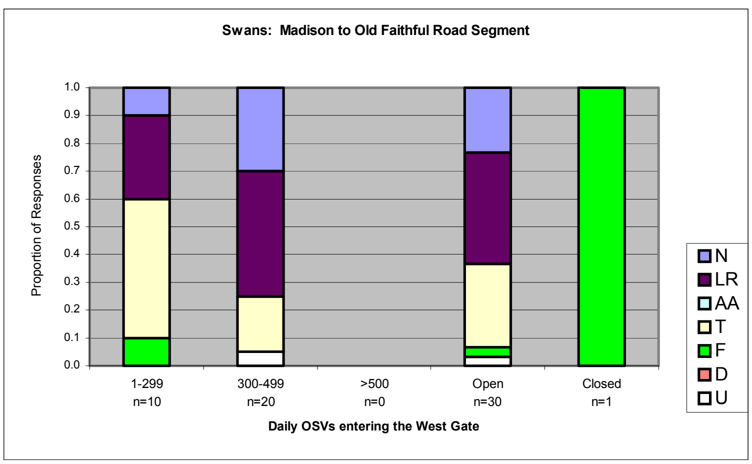


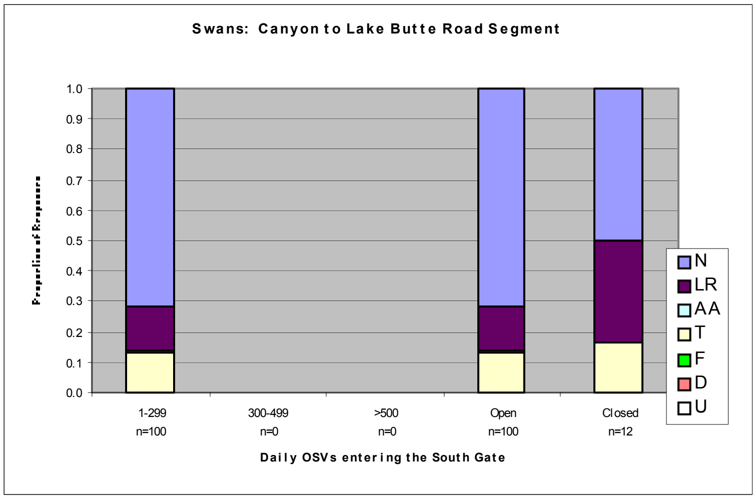
Elk: Madison to Norris Road Segment
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Proportion of Reponses
1-299
n=4
300-499
n=4
>500
n=1
Open
n=9
Closed
n=0
Daily OSVs entering the West Gate
N
LR
AA
T
F
D
U

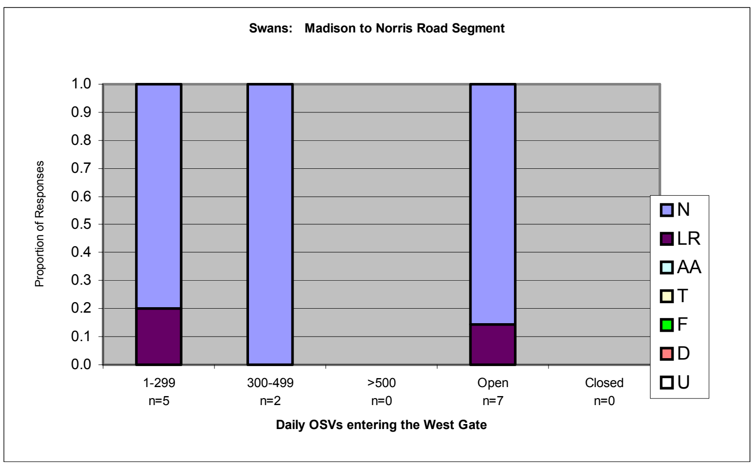


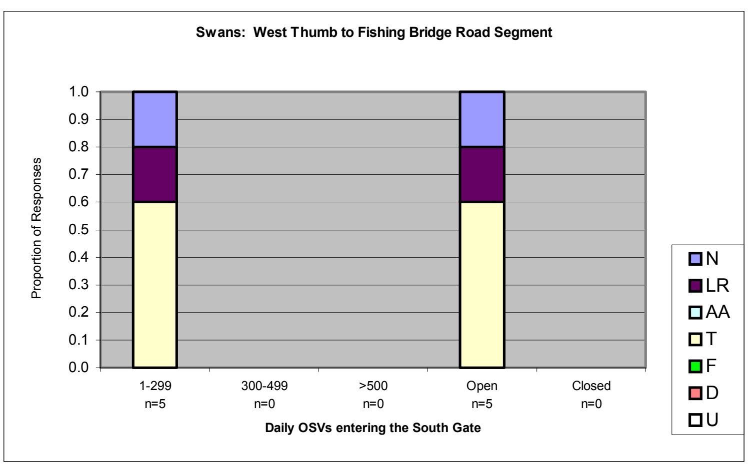
Trumpeter Swans





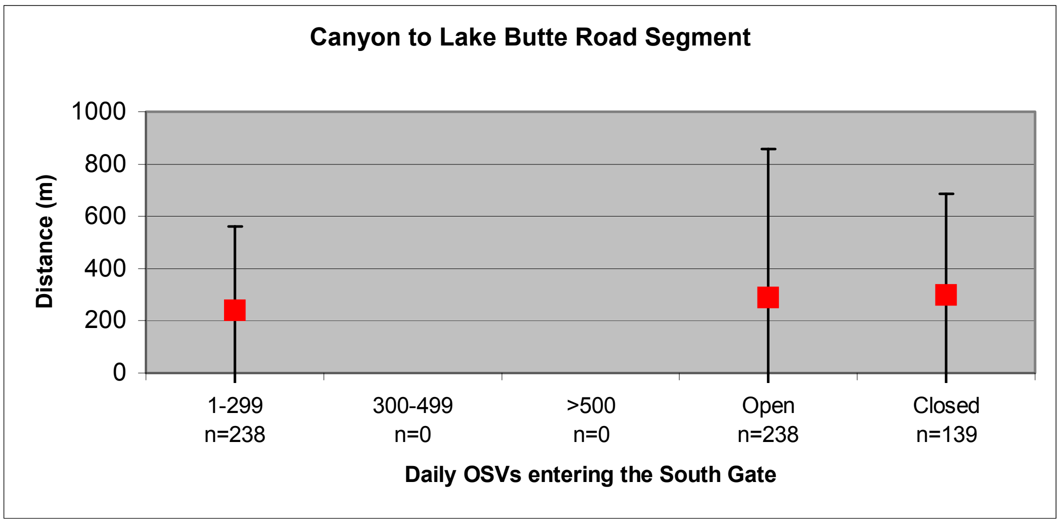

Swans: Canyon to Lake Butte Road Segment
Proportion of Responses
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1-299
n=100
300-499
n=0
>500
n=0
Open
n=100
Closed
n=12
Daily OSVs entering the South Gate
N
LR
AA
T
F
D
U

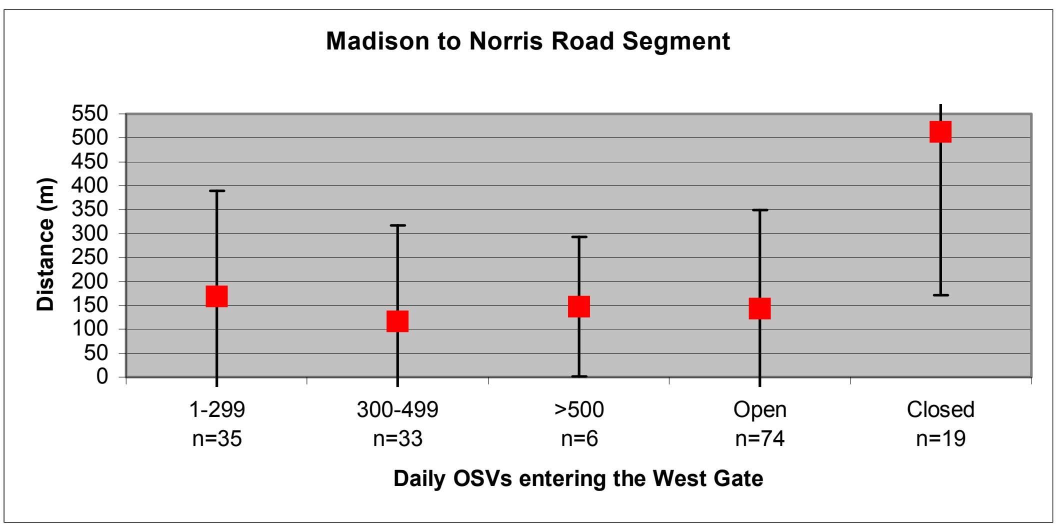

Swans: Madison to Norris Road Segment
Proportion of Responses
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1-299
n=5
300-499
n=2
>500
n=0
Open
n=7
Closed
n=0
Daily OSVs entering the West Gate
N
LR
AA
T
F
D
U

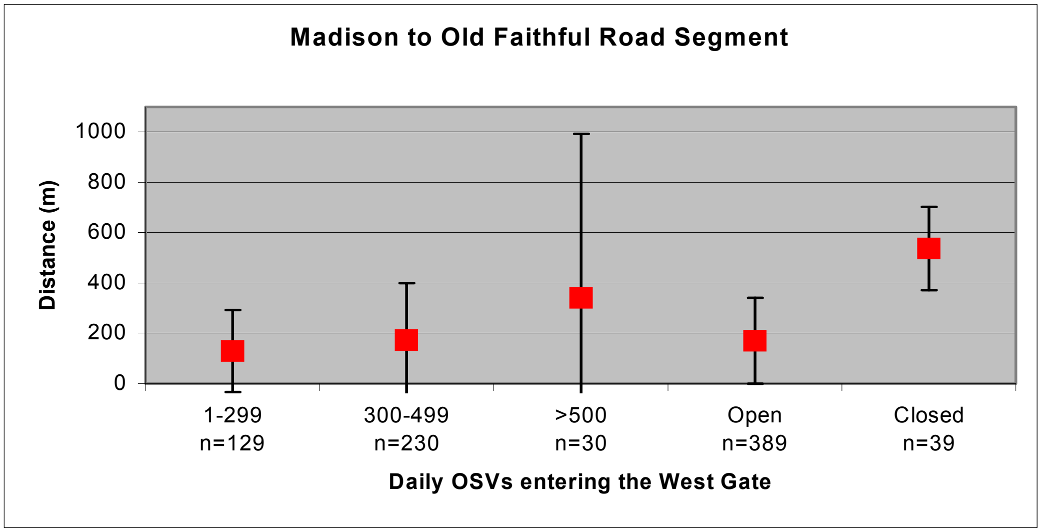

Swans: West Thumb to Fishing Bridge Road Segment
Proportion of Responses
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1-299
n=5
300-499
n=0
>500
n=0
Open
n=5
Closed
n=0
Daily OSVs entering the South Gate
N
LR
AA
T
F
D
U

Appendix H: Bison, elk, and trumpeter swan distances (mean ± SD; meters) from road segments in the west-central portion of Yellowstone National Park plotted against categorical levels of over-the-snow vehicle traffic that entered the West Entrance Station during winter 2002-03. Categories included periods when the park was closed to public over-the-snow vehicle travel compared to when the park was open to public over-the-snow vehicle travel, and when 1-299, 300-499, and >500 over-the-snow vehicles entered the study area via the West Entrance Station. Observations in which distance was not recorded are not included in this appendix.

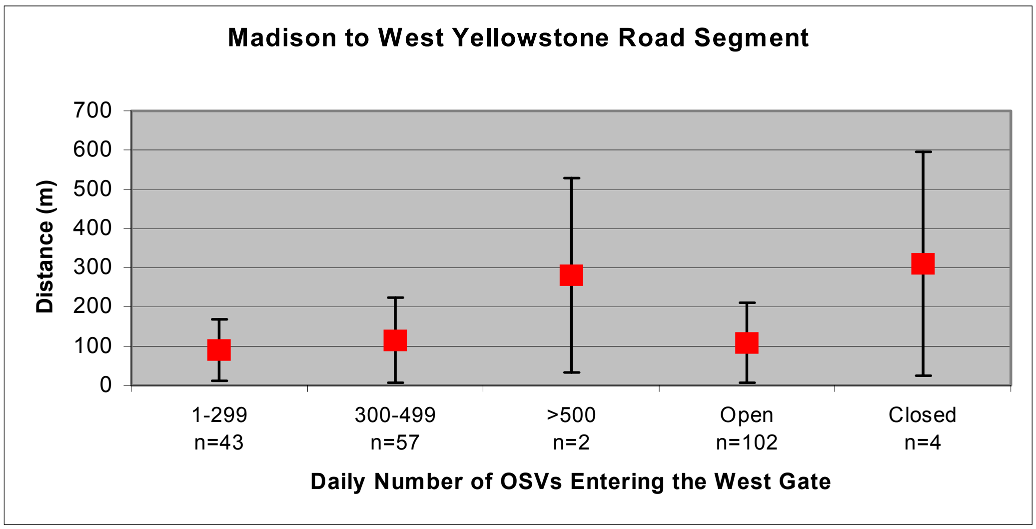
Bison



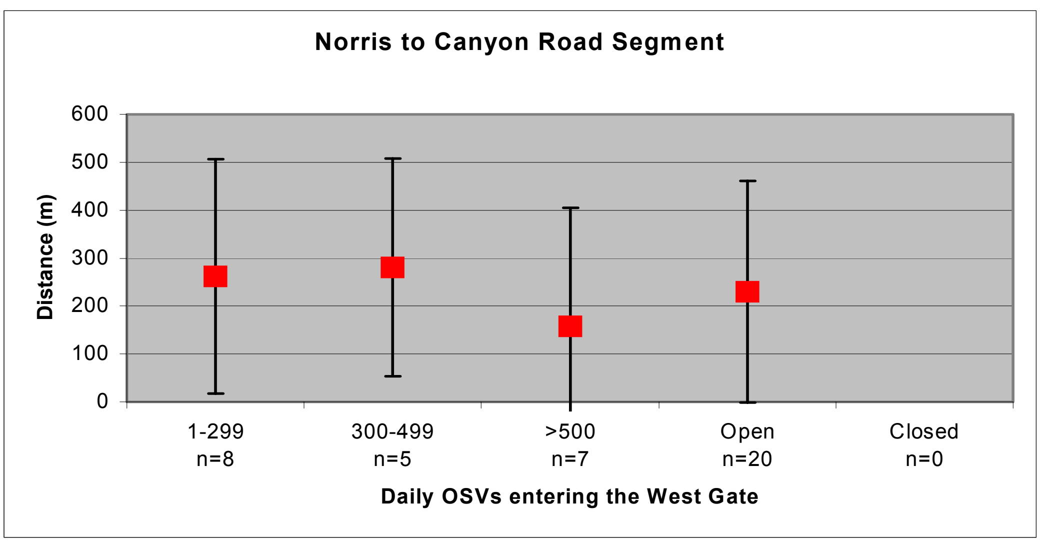




Madison to Old Faithful Road Segment
Distance (m)
1000
800
600
400
200
0
1-299
n=129
300-499
n=230
>500
n=30
Open
n=389
Closed
n=39
Daily OSVs entering the West Gate

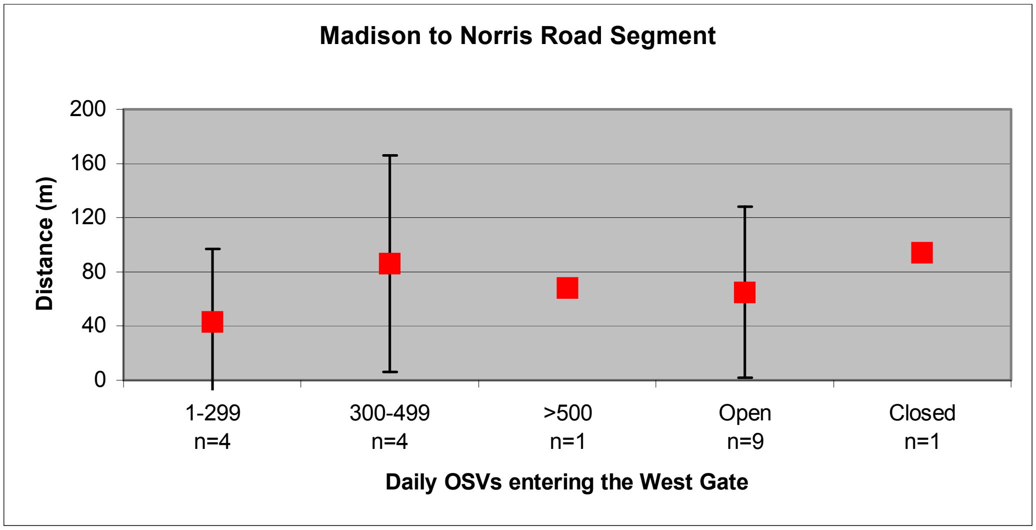


Madison to West Yellowstone Road Segment
Distance (m)
700
600
500
400
300
200
100
0
1-299
n=43
300-499
n=57
>500
n=2
Open
n=102
Closed
n=4
Daily Number of OSVs Entering the West Gate

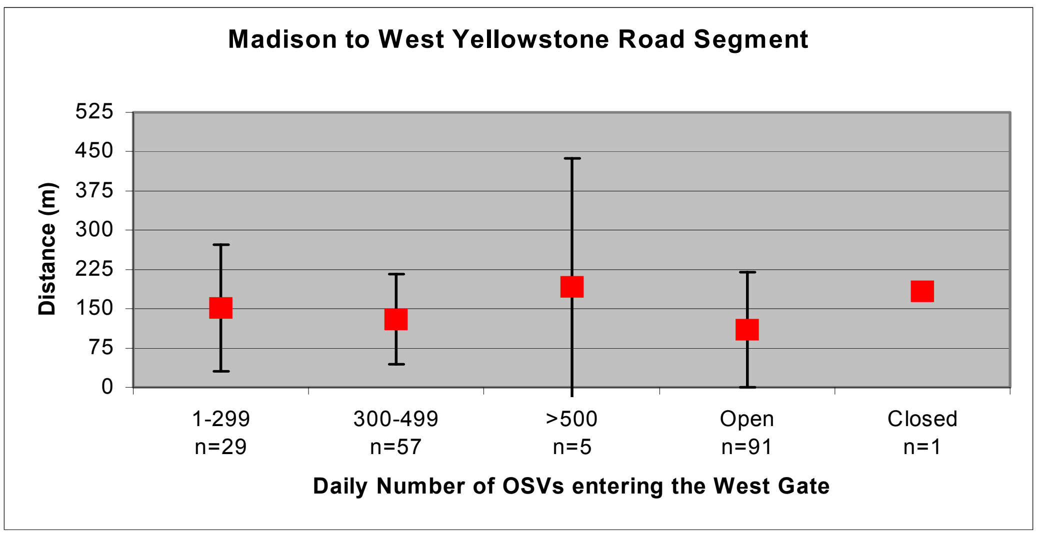


Norris to Canyon Road Segment
Distance (m)
600
500
400
300
200
100
0
1-299
n=8
300-499
n=5
>500
n=7
Open
n=20
Closed
n=0
Daily OSVs entering the West Gate

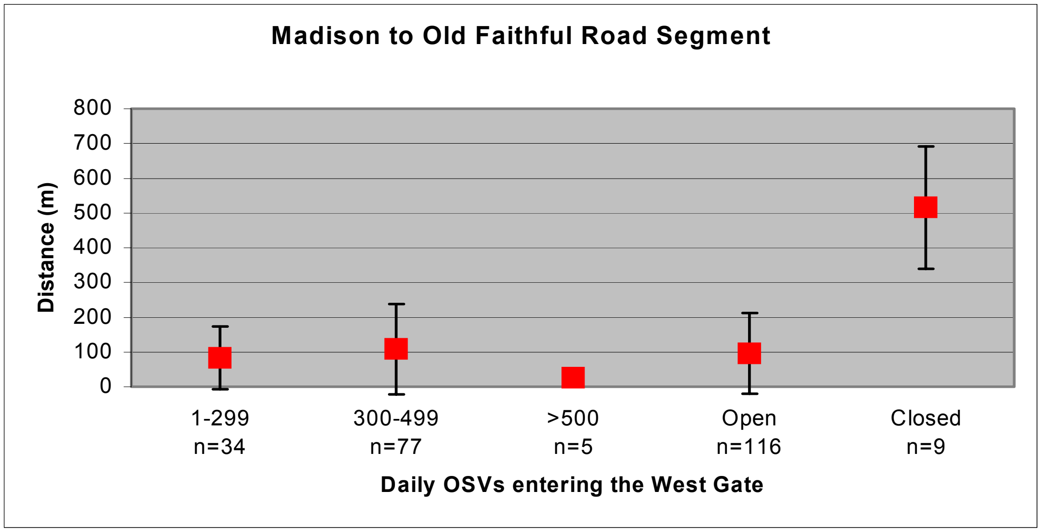
Elk

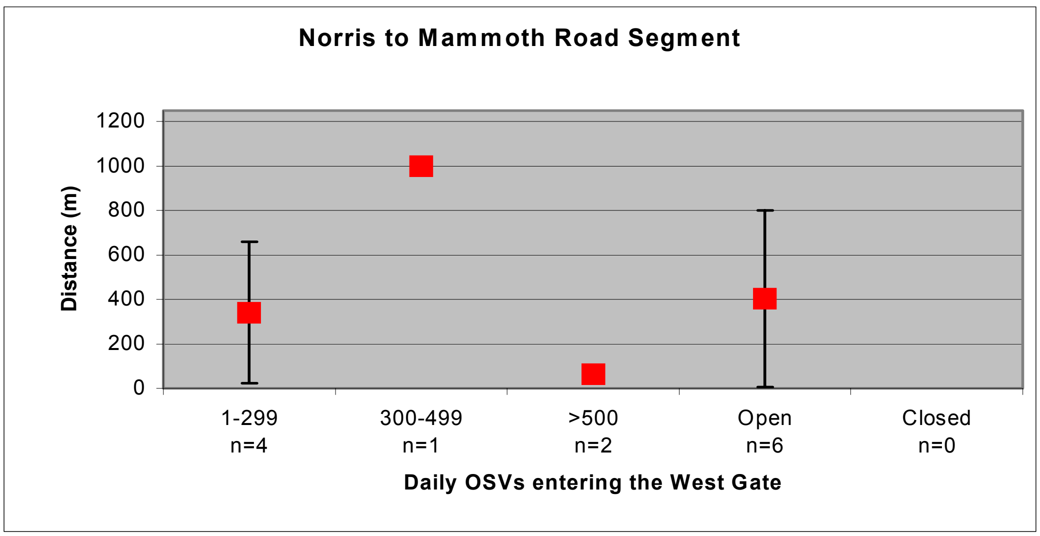


Madison to Norris Road Segment
Distance (m)
200
160
120
80
40
0
1-299
n=4
300-499
n=4
>500
n=1
Open
n=9
Closed
n=1
Daily OSVs entering the West Gate

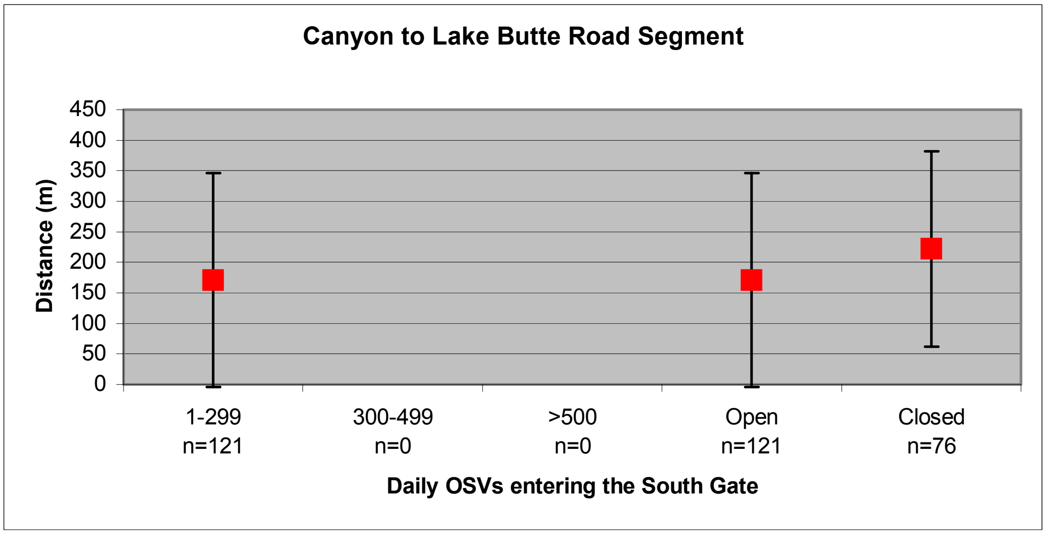


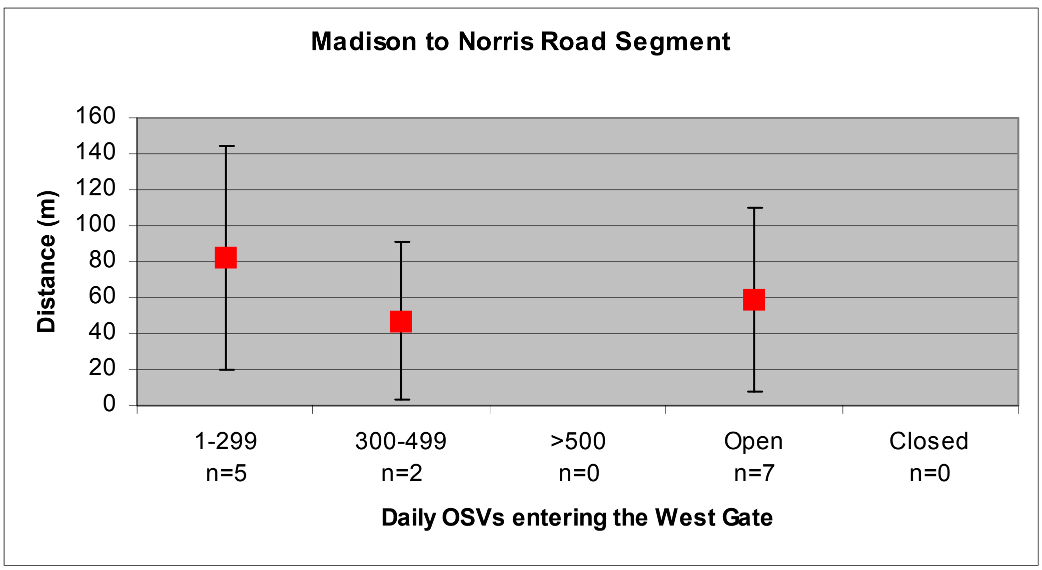
Madison to West Yellowstone Road Segment
Distance (m)
525
450
375
300
225
150
75
0
1-299
n=29
300-499
n=57
>500
n=5
Open
n=91
Closed
n=1
Daily Number of OSVs entering the West Gate

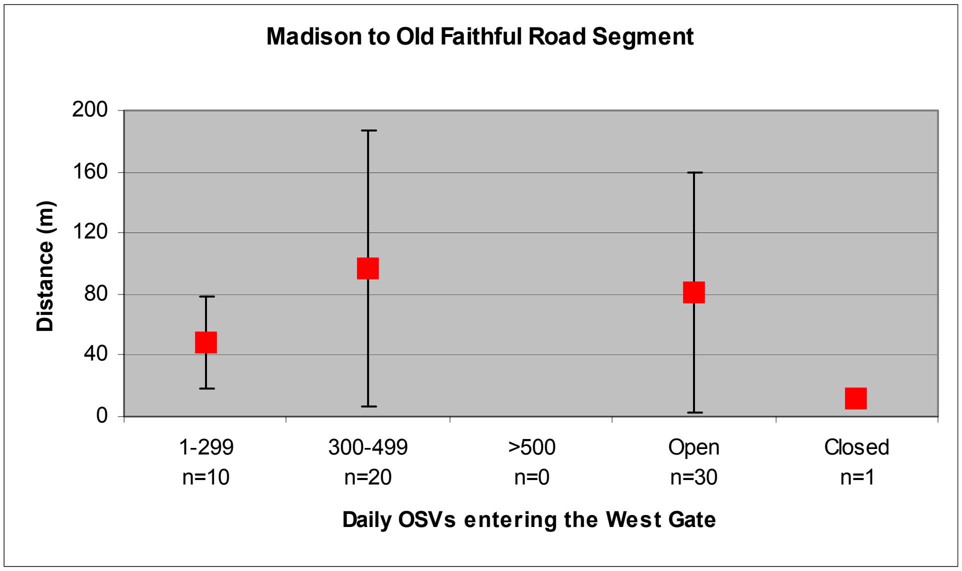

Madison to Old Faithful Road Segment
800
700
600
500
400
300
200
100
0
Distance (m)
1-299
n=34
300-499
n=77
>500
n=5
Open
n=116
Closed
n=9
Daily OSVs entering the West Gate

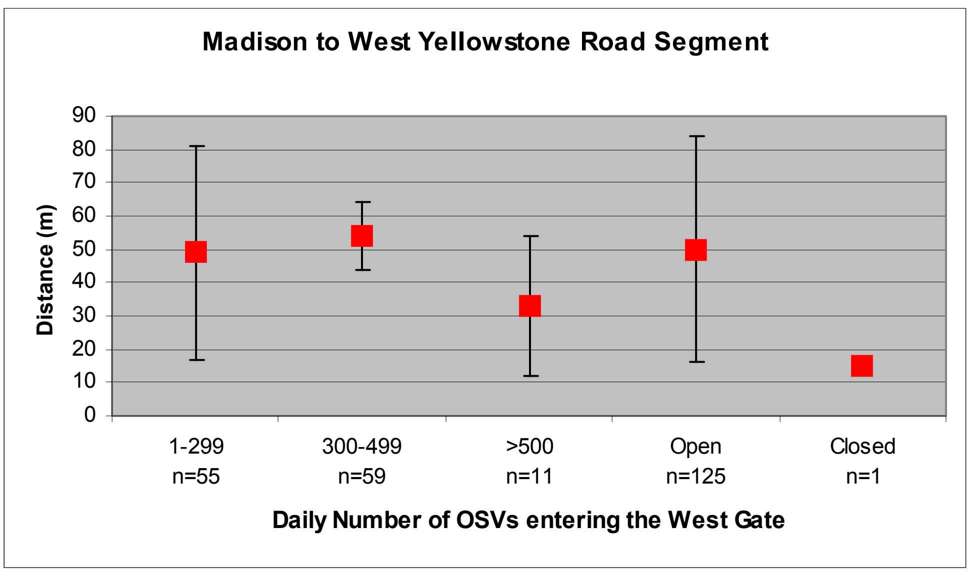

Norris to Mammoth Road Segment
1200
1000
800
600
400
200
0
Distance (m)
1-299
n=4
300-499
n=1
>500
n=2
Open
n=6
Closed
n=0
Daily OSVs entering the West Gate

Trumpeter Swans






Madison to Old Faithful Road Segment
Distance (m)
200
160
120
80
40
0
1-299
n=10
300-499
n=20
>500
n=0
Open
n=30
Closed
n=1
Daily OSVs entering the West Gate


Madison to West Yellowstone Road Segment
Distance (m)
90
80
70
60
50
40
30
20
10
0
1-299
n=55
300-499
n=59
>500
n=11
Open
n=125
Closed
n=1
Daily Number of OSVs entering the West Gate