MONTANA STATE UNIVERSITY

Impacts of winter recreationists on wildlife in a portion of Yellowstone National Park, Wyoming
by Keith Edward Aune

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Fish and Wildlife Management
Montana State University
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Abstract:
The impacts of winter recreationists on wildlife in Yellowstone National Park were investigated from 1978-80, Total winter visitation has increased 995 per cent since 1966 and exceeded 50,000 visitors the winter of 1979-80. Winter recreation includes such activities as snowmobiling, cross-country skiing, snowshoeing, winter camping, and snowcoach tours through the park. The number of private oversnow vehicles entering the park ranges from 20,000 to 30,000 per year.

Over 15,000 snowcoach passengers travel through the park each year.

The general responses of wildlife to disturbance include: Attention or alarm response, flight response, and aggressive response. Only two instances of aggresssive responses were recorded. Flight and attention responses varied with the species involved. The response of wildlife to snowmobiles was more intense and more frequent in the control area than along the groomed snowmobile trail. Wildlife reactions were more frequent and intense during the preseason period than during the recreation season. Much of the wildlife-snowmobile interaction occurred while elk or bison traveled on the groomed trail. Elk were the most frequently encoutered wildlife species followed by bison, coyote, mule deer, and moose. Ninety-four percent of the encounters were within the 0-60 meter encounter distance range. Ninety-one per cent of the distances of flight recorded for all species were less than 100 meters. Wildlife-skier interaction per mile skied and the per cent of wildlife responding by fleeing was greater than for snowmobiling. Average encounter distance and average distance of flight for all species combined were greater for approaches by skiers than by snowmobile. Wildlife-skier interaction was greater off the trails than on the established trails. Wildlife developed crepuscular activity patterns in response to winter recreation activity. Winter recreation activity in Yellowstone was not a major factor influencing wildlife distribution, population, or movement. Some displacement of wildlife from areas adjacent to the trails was observed. Wildlife movement across the trails was inhibited by intense traffic and by the berm created by plowing and grooming operations. Harrassment of wildlife by snowmobiles and skiers increased energy expenditure of wildlife. Elk, mule deer, and bison were observed to habituate to the snowmobile noise. The observed effects of winter recreationists on the physical environment include: minor air and snow pollution by snowmobile exhaust, litter, noise pollution, and limited physical damage to soils and plants.

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by

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A thesis submitted in partial fulfillment of the requirements for the degree

of

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in

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Approved:

Chairman, Graduate Committee

Head, Major Department

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ABSTRACT

The impacts of winter recreationists on wildlife in Yellowstone National Park were investigated from 1978-80. Total winter visitation has increased 995 per cent since 1966 and exceeded 50,000 visitors the winter of 1979-80. Winter recreation includes such activities as snowmobiling, cross-country skiing, snowshoeing, winter camping, and snowcoach tours through the park. The number of private oversnow vehicles entering the park ranges from 20,000 to 30,000 per year. Over 15,000 snowcoach passengers travel through the park each year. The general responses of wildlife to disturbance include: Attention or alarm response, flight response, and aggressive response. Only two instances of aggresssive responses were recorded. Flight and attention responses varied with the species involved. The response of wildlife to snowmobiles was more intense and more frequent in the control area than along the groomed snowmobile trail. Wildlife reactions were more frequent and intense during the preseason period than during the recreation season. Much of the wildlife-snowmobile interaction occurred while elk or bison traveled on the groomed trail. Elk were the most frequently encoutered wildlife species followed by bison, coyote, mule deer, and moose. Ninety-four percent of the encounters were within the 0-60 meter encounter distance range. Ninety-one per cent of the distances of flight recorded for all species were less than 100 meters. Wildlife-skier interaction per mile skied and the per cent of wildlife responding by fleeing was greater than for snowmobiling. Average encounter distance and average distance of flight for all species combined were greater for approaches by skiers than by snowmobile. Wildlife-skier interaction was greater off the trails than on the established trails. Wildlife developed crepuscular activity patterns in response to winter recreation activity. Winter recreation activity in Yellowstone was not a major factor influencing wildlife distribution, population, or movement. Some displacement of wildlife from areas adjacent to the trails was observed. Wildlife movement across the trails was inhibited by intense traffic and by the berm created by plowing and grooming operations. Harrassment of wildlife by snowmobiles and skiers increased energy expenditure of wildlife. Elk, mule deer, and bison were observed to habituate to the snowmobile noise. The observed effects of winter recreationists on the physical environment include: minor air and snow pollution by snowmobile exhaust, litter, noise pollution, and limited physical damage to soils and plants.

INTRODUCTION

Significant changes have occurred in winter use of Yellowstone National Park since the early 1960's. Prior to 1963, winter visitation to Yellowstone Park was very limited. The development of efficient oversnow vehicles and winter recreation facilities within the park has contributed to increased winter visitation which exceeded 50,000 during 1979-80. Since 1966, the total number of visitors to the park during the winter has risen 955 per cent. This presents new and challenging management problems associated with retaining natural ecological relationships in the face of increased recreational use and the accompanying impacts. Houston (1971) noted that "Providing for the educational and esthetic enjoyment of man while maintaining pristine ecological relationships, represents the greatest challenge in the management of natural areas."

Winter recreation in Yellowstone National Park includes such activities as snowmobiling, cross-country skiing, snowshoeing, winter camping, and scenic snowcoach tours through the park. These activities have the potential to adversely impact wildlife and the natural winter environment. To date, little research has been done on specific impacts of such activities on wildlife in the winter environment. Schmid (1971), Jarvinen and Schmid (1971), and Pruitt (1971) discuss the impacts of snowmobiles on the subnivean environment. Newmann and Merriam (1972) reported the effects of snowmobiling on snowshoe hare (Lepus americanus) and red fox (Vulpes fulva) mobility and distribution. Dorrance, et al. (1975), Huff and Savage (1975), Eckstien and Rongstad (1973), Richens and Lavigne (1978), and Bury (1978) examined the impacts of snowmobiles on white-tailed deer (Odocoileus virginianus). Bollinger (1973) provided a study on the effects of snowmobile noise on wildlife. Schultz and Bailey (1978), Young and Boyce (1971), and Bayfield (1970), mention some impacts of skiing on wildlife and the environment. Several other authors report impacts of snowmobiles on soil and vegetation (Wanek 1971, 1973, Whittaker 1971, Baldwin 1969, 1971, and Newmann and Merriam 1972).

This study represents the first intensive investigation to assess the impacts of winter recreationists upon wildlife and the environment in Yellowstone National Park. The primary objectives were: 1) classify recreational use density and distribution within the study area; 2) to determine the acute and chronic reactions of wildlife to recreationists and implications of effects on energy balance; 3) to determine any adverse effects on the general quality of the winter environment in the study area. Considerable emphasis was placed on the impacts of oversnow vehicles and cross-country skiers on elk (Cervus elaphus nelsoni) and bison (Bison bison), the two most numerous ungulates within the study area. Field work was conducted from November 1978 until April 1979 and from December 1979 until April 1980.

DESCRIPTION OF THE STUDY AREA

Location, Physiography, and Geology

The study area includes portions of the Madison, Firehole, and Gibbon River valleys inside Yellowstone National Park between the elevations of 2000 to 2400 meters (Figure 1). Craighead, et. al. (1973) and Cole (1972 and 1978) gave brief descriptions of the area. A general description of the physiography of the park was given by Meagher (1973). Extensive volcanism and glaciation shaped many of the physiographic features. The unusual geology of the park has been discussed by Hague (1899), Fischer (1976), and Keefer (1976). Soils are mainly derived from volcanic rhyolite.

Vegetation

General descriptions of Park vegetation are provided by Bailey (1930), Bailey and Bailey (1949), McDougall and Baggley (1956), Meagher (1973), Despain (1973), Barmore (1975), and Houston (1976). About three-fourths of the study area is dominated by moderate to very dense stands of lodgepole pine (*Pinus contorta*) forest. The lodgepole pine zone is dominated by climax lodgepole pine or seral stages with very little or no spruce or fir in the understory (Despain, 1973). A small portion of the Madison River Valley is occupied by Douglas-Fir (*Pseudotsuga menziesii*) in conjunction with open sagebrush/grasslands. Other habitat types present are meadows or parks (covering about 20 percent of the study area) and scattered geothermal areas (Cole 1972).

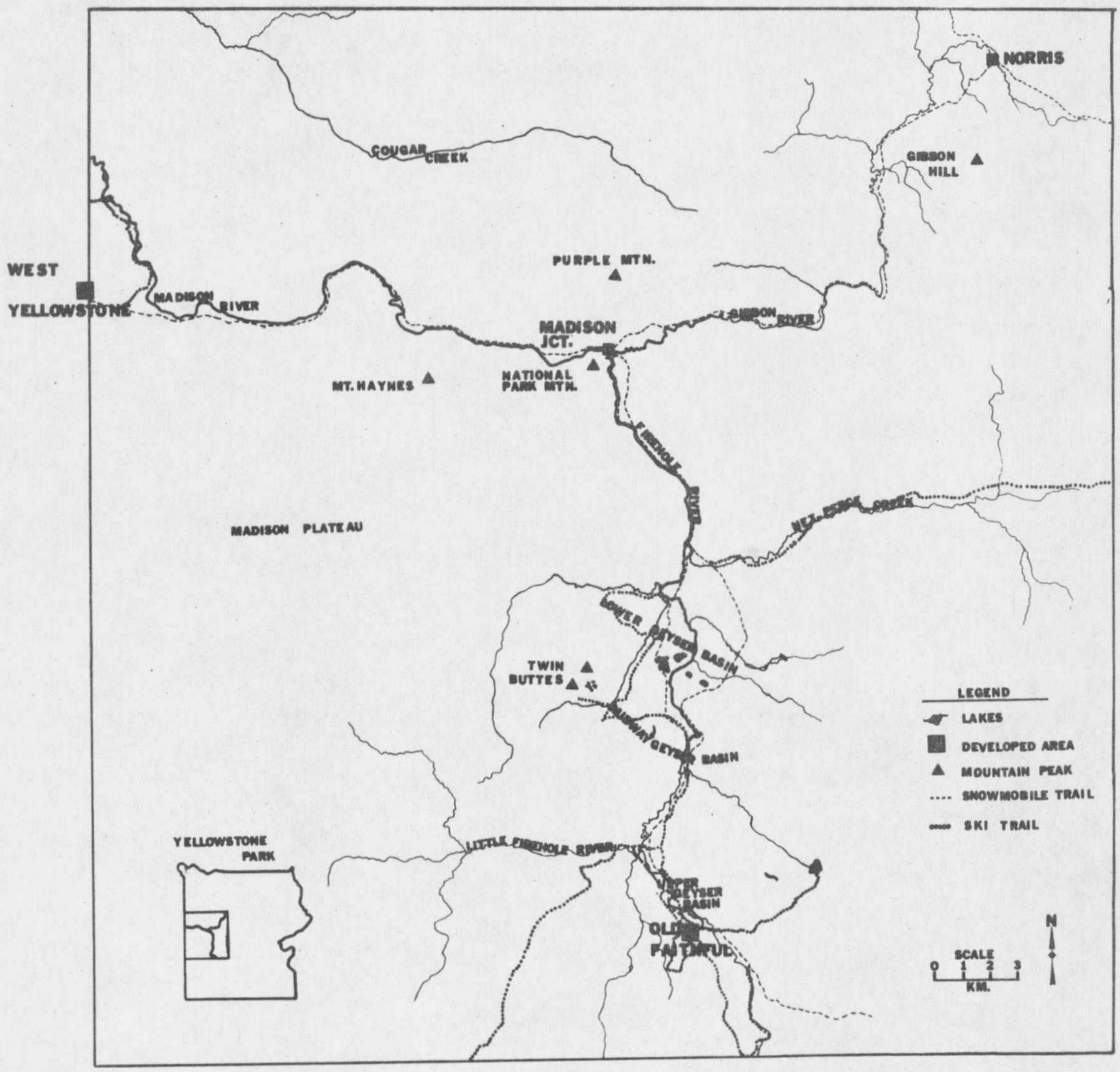

Figure 1. Map of the Study Area

The meadows are characterized by grasses, sedges (Carex spp.), marsh reedgrass (Calamagrostis spp.) and willows (Salix spp.). The dominant grasses of drier sites are Idaho fescue (Festuca idahoensis) and bluegrass (Poa spp.)

Climate

Houston (1976) gave a comprehensive history of climatic changes in Yellowstone Park. Presently the climate is characterized by long, cold winters and short cool summers. U.S. Department of Commerce (NOAA) records for West Yellowstone, Montana show the mean annual temperature for 1940-1969 was 1.7°C, 15.3°C for July was the warmest month and a -10.6°C for January the coldest month. Midwinter extremes are bitterly cold; the coldest observed in the basin was -66°F on February 9, 1933. Most of the subzero weather in the area appears to be generated locally as a combined result of clear sky nocturnal radiation cooling from a substantial and consistent snowpack (U.S. Dept. of Commerce). Annual precipitation for the 1940-1969 period was 58.3 cm., most of it falling as snow during the winter months. Mean annual snowfall was 418 cm. and mean depth exceeded 46 cm. for an average of 126 days per year.

Fauna

In the Firehole, Gibbon, and Madison river valleys there are about 16,200 ha. of winter habitat which supports about 800 elk and from 100 to 500 Bison as well as small numbers of moose (Alces alces) and mule deer (Odocoileus hemionus) (Cole 1978). Secondary consumers common to the area include coyotes (Canis latrans), black bear (Ursus americanus), grizzly bears (Ursus arctos), and a host of avian scavengers and predators. Mountain lions (Felis concolor) and wolverine (Gulo luscus) are reported occasionally. Endangered or threatened species present in the area include grizzly bears, bald eagles (Haliaeetus leucocephalus), and trumpeter swans (Olor buccinator) with occasional reports of gray wolves (Canis lupus). A large number of Canada geese (Branta canadensis) and several species of ducks winter on rivers in the study area. Thermal activity along the Gibbon, Firehole, and Madison rivers produce conditions under which the wildlife can winter. Thermal input to rivers keep them relatively ice-free which attracts wintering populations of bald eagles, trumpeter swan, Canada geese, bald eagles, and other waterfowl. This open water is also important to beaver (Castor canadensis) and river otter (Lutra canadensis) inhabiting the area.

History of Winter Use

Prior to 1955, snow conditions and unplowed roads kept most of the park inaccessible except to those visitors who ventured into the park on snowshoes or skiis. Snowplanes came into the park prior to World War II and the Park Service operated one or two after the war as well as "weasels". The only motorized access was by the north entrance road from Gardiner, Montana, to Mammoth, Park headquarters.

The first permit issued to operate snowmobiles in Yellowstone Park was given on January 18, 1955 to William J. Nicholes and Harold M. Young of West Yellowstone who had formed a partnership under the name Snowmobiles of West Yellowstone. Their concession provided for carrying passengers on occasional trips to Old Faithful from West Yellowstone. The permit was for one year. When the operation proved successful, the Park Service offered a longer franchise to the Yellowstone Park Company who accepted it and contracted with Snowmobiles, Inc. of West Yellowstone to provide the service. In 1966, the Yellowstone Park Company purchased the snowcoaches and began to operate them. In 1967, they began to operate coaches out of Mammoth Hot Springs as well as West Yellowstone and the Canyon Village run was started. In 1971, Snowlodge was opened for its first winter of operation.

The first privately owned snowmobiles began operating in the park during the winter of 1963-1964. The first snowmobile rally was held at West Yellowstone, Montana in 1964-1965. On that one day 60-70 private machines came into Old Faithful from West Yellowstone. Seven or eight machines a day was considered heavy use at that time. Unrestricted, unregulated, uncontrolled snowmobile use within the park was deemed unacceptable by the National Park Service. However, regulated use, which meant restricting the travel of snowmobiles to the roads utilized by conventional motor vehicles at other times of the year, appeared to be reasonable and acceptable.

Yellowstone Park Company began grooming the trail for snowcoaches as early as 1969. In 1970 or 1971, the National Park Service began trail grooming operations.

At the present time aside from the operation of facilities at Old Faithful Village, warming stations are operated at Madison Junction, West Thumb, and Canyon Village. Three hundred and forty two kilometers of unplowed roads are groomed regularly and heavily used areas are groomed almost daily. Over 30,000 privately owned snowmobiles enter the park each year. On days receiving heavy use as many as 1000 snowmobiles will travel from West Yellowstone to Old Faithful. Snowcoaches transport over 10,000 persons a season throughout the Park. Approximately 80 km. of ski trails are present within the study area.

METHODS

Cover Use, Distribution and Behavior of Wildlife

Wildlife cover use, distribution and behavior data were obtained while snowmobiling and skiing on roads and trails throughout the study area. The area of each habitat type present was determined using a planimeter on a current vegetation map of the area. Each snowmobile trip consisted of a relatively fixed circuit on the major roads in the study area. The mileage and riding time for each day were recorded. A control route of 5.6 km. where snowmobiling by park visitors was not allowed was travelled at random intervals during the winter to compare wildlife reactions to snowmobiles in an unused area to responses in well used areas. Ski tours were made off as well as on the established trails. Time and mileage during each ski trip were also recorded.

Observations and Encounters

According to Chester (1976) a wildlife encounter is defined as a mutual interaction between humans and the animal encountered. An observation would not necessarily involve a mutual interaction. This definition was adopted and the methods employed by Chester (1976) to study human and wildlife interaction were modified to fit this study. At each approach to wildlife, data were gathered about encounter distance, distance of flight, behavioral response to approach, activity engaged in upon approach, and distance from the road or trail. Number, sex, age, and habitat type data were also recorded. Observations were recorded for all species of wildlife encountered.

Aerial Observation

Six aerial observation flights were made in 1978-79 and 3 in 1979-80 in a Piper Super Cub to supplement ground observations. Distribution of wildlife was recorded using UTM coordinates. Core and peripheral big game wintering areas were identified using these data. Once delineated core and perpheral ranges were planimetered on a map to determine area.

Intensity and Distribution of Human Use

The National Park Service provided entrance records, historical information, back-country use data, and data from electric eyes placed on several major roads and ski-trailheads. The Yellowstone Park Company and TWA Services also provided historical and current use data relating to the concessioner operation. Personal observation provided additional data on winter recreationist distribution.

Impacts of Recreationists on the Winter Environment

Snow and air samples were collected to determine gross hydrocarbon and lead input to the ecosystem by snowmobile exhaust emissions. Personal observations of smog due to engine exhaust, litter, and damage to the soil or vegetation by snowmobiles and skiing were also recorded.

Snow samples were collected weekly in the Old Faithful area during January and February of 1980. Samples were collected with a standard "Federal Snow Sampler." Core samples of the entire column of snow were taken from the groomed trail, adjacent to the trail, at 30 m from the road and from a control area. These samples were placed in one liter plastic bottles, frozen, and transported to Montana State University for analysis of lead and total organic carbon.

Analysis for organic carbon was conducted by research personnel at the MSU Chemistry Department. In the laboratory triplicate 5 ml. aliquots of the sample were transferred to precombusted glass ampoules (Oceanography International) containing 0.25 gm. potassium persulfate. A Hamilton "Gas-Tite" syringe was used for the transfer. Six percent H_3PO_4 (0.25 ml) was added to each ampoule. Each sample was purged for 8 minutes with oxygen which had been passed over a catalyst at 500°C and sealed in Oceanography International ampoule sealing unit. Sealed ampoules were autoclaved at 15 psc for about 15 hours (overnight). Samples were then analyzed using a Total Carbon analyzer (Oceanography International).

Analysis for lead was conducted also at Montana State University. In the laboratory a core sample from the one liter plastic bottles was taken using a glass tube snow sampler. The sample was melted down and two percent distilled HNO_3 was added to make the sample more homogeneous. These were then placed into a Woodriff furnace type atomizer and analyzed by atomic absorption.

Contamination of the snow samples using the methods discussed above proved to be a considerable problem. A second set of snow samples was collected when the maximum snow accumulation on the ground was reached. Samples of the entire column of snow adjacent to the road and at 30 meters from the road were taken. In order to minimize possible contamination from sample handling, clean glass core samplers were used to extract these samples. The core was cut into two inch increments and each increment placed in a cleaned glass container so only lead free surfaces came into contact with the snow. The samples were analyzed by atomic absorption.

A simple low volume air sampling technique was used in 1978-79 to determine if snowmobile exhaust emissions caused a significant air pollution problem. Staplex TFA #41 filters were used in the sampler which was set to draw air at the rate of 30 cf/min. for a 2 hour sampling period. Filters were weighed before and after sampling on a Mettler balance. The air samples were taken monthly from January to March at one sampling station. The December sample was taken at four stations. The air sampler was powered by a portable generator when electrical outlets were not accessable. When powered by the generator care was taken to place the generator unit down wind at least 30 meters from the sampler.

In 1979-1980 air was sampled for lead and the low volume sampling technique discontinued because of negative results. Lead analysis of air was accomplished by pulling a known quantity of air through a porous graphite cup housed in a teflon container. The air was pulled through the cup using a 60 cc plastic syringe. The graphite cup was transported to the lab in cleaned closed containers and placed in a Woodriff furnace type atomizer where it was analyzed by atomic absorption. Air samples were taken on random days each week, one sample each hour of the day between 8:00 A.M. and 5:00 P.M. All samples were taken in Old Faithful Village.

RESULTS

Wildlife Populations Distributions and Cover Use

Core and Peripheral Winter Ranges

Core and peripheral winter ranges were delineated primarily (Figure 2) with the data collected during aerial and ground surveys of elk and bison distribution. Information on topography and vegetation types supplemented the distribution data. During the winters of 1978-79 and 1979-80, elk and bison were distributed across an area of approximately 18,688 hectares within an elevational range of 2011 meters to 2377 meters. Peripheral ranges encompassed an area of 13,080 hectares and were used primarily during early winter and early spring when snow depth and conditions allowed occupation of these areas. Core ranges encompassed an area of 5608 hectares and are used heaviest during the severe winter months of January through early March.

Habitat Types Present on Winter Ranges

The relative amount of each habitat type present within the study area is presented in Table 1. Six nonforested and ten forested habitat types have been identified and mapped within the area. For a complete description of each habitat type see Despain (1980). Nonforested types identified by Despain (1980) include: sedge type (*Carex spp.*), hot springs-warm ground type, willow-sedge (*Salix spp./Carex spp.*), tufted hairgrass/sedge (*Deschampsia caespitosa/carex spp.*), big

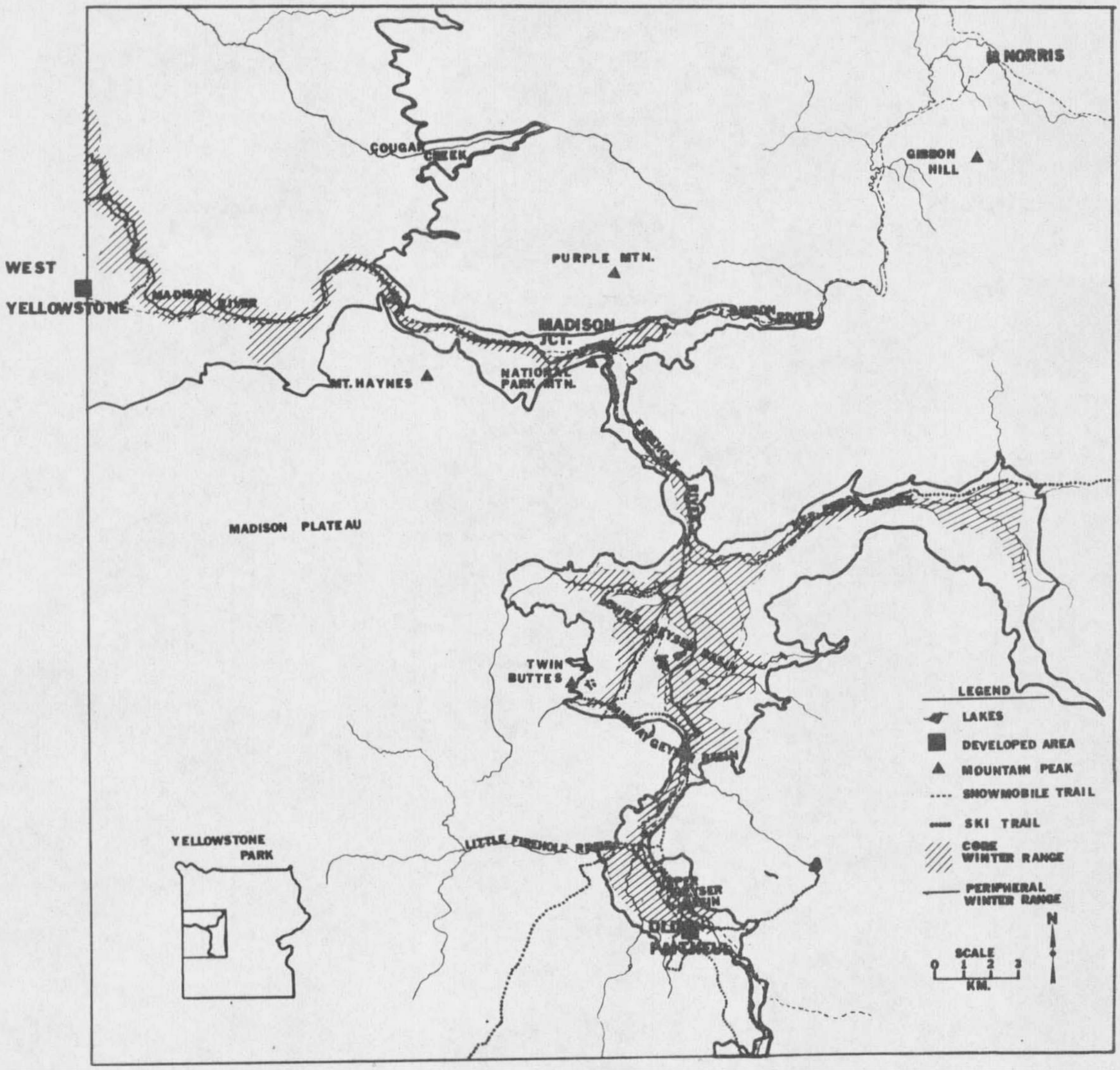

Figure 2. Core and peripheral winter ranges of elk and bison, 1978-80.

Table 1. Percentage and hectares present of each habitat type occurring within the study area.

Habitat Type	Percent	Hectares
Abla/Vasc h.t. Vasc	17.0	3,170
Abla/Vasc h.t. Caru	3.3	622
Abla/Cage	3.7	697
Abla/Libo h.t. Vasc	0.2	40
Abla/Vagl h.t. Vagl	0.3	64
Abla/Caru	21.4	3,996
spruce-fir-lodgepole wet forests	3.9	723
Pico/Cage	0.8	142
Pico/Putr	29.4	5,491
Psme/Caru	3.0	570
Nonforested combined[1]	17.0	3,173
Total	100.0	18,688

[1] Nonforested types combined include all grassland/sedge, hot springs-warm ground, willow/sedge, and sagebrush/grassland types.

sagebrush/Idaho fescue (Artemesia tridentata/Festuca idahoensis), and a big sagebrush type in a moister phase. Because of the difficulty observing the understory beneath a blanket of snow, Despain's types were modified into four broader types which could be distinguished during the Winter months. These four winter habitat types included: grassland/sedge, willow/sedge, hot springs-warm ground, and big sagebrush/grassland types. Grassland/sedge and hot springs-warm ground were the dominant nonforested types within the study area. Big sagebrush/ grassland and willow/sedge types comprised less than five percent of the total surface area.

Forested types reported to occur in the study area include: subalpine fir/ grouse whortleberry - h.t. grouse whortle berry phase (Abies lasiocarpa/Vaccinium scoparium - V. scoparium), a wet spruce-fir forest type, subalpine fir/elk sedge (Abies lasiocarpa/Carex geyeri), subalpine fir/pinegrass (Abies lasiocarpa/Calamagrostis rubescens), lodgepole pine/elk sedge (Pinus contorta/Carex geyeri), lodgepole pine/bitterbrush (Pinus contorta/Purshia tridentata), douglas-fir/pinegrass (Pseudotsuga menziesii/Calamagrostis rubescens), subalpine fir/twin flower h. t. grouse whortleberry phase (Abies lasiocarpa/Linnaea borgalis-Vaccinium scoparium), and subalpine fir/ globe huckleberry h.t. globe huckleberry phase (Abies lasiocarpa/ Vaccinium globulare - V. globulare).

The core winter ranges on the Madison River included grassland/ sedge, sagebrush/grassland, willow/sedge, and timbered vegetation types within an elevational range of 2011 meters to 2073 meters. Peripheral ranges were mostly timbered types in the elevational range of 2073 meters and 2133 meters. Core winter range on the Firehole River included timbered, grassland/ sedge, and hot springs habitat within an elevational range of 2164 meters to 2255 meters. Peripheral ranges included timbered, small grassland/sedge meadows, and scattered hot springs vegetation types between the elevations of 2255 meters and 2377 meters.

Core winter ranges were comprised of 2810 hectares (50.1%) nonforested types and 2798 hectares (49.9%) forested types. Peripheral ranges were occupied by 363 hectares (2.8%) nonforested types and 12,717 hectares (97.2%) forested types.

Elk Population, Distribution and Habitat Use

Winter population census records for the years 1965 to 1980 are presented in Table 2. During this study a maximum count of 951 elk occurring in the Madison, Firehole, and Gibbon river drainages was made on January 29, 1980. The elk population has remained relatively stable since 1965 fluctuating between 593 and 959 elk. The Gibbon and Firehole River population segments where the thermal basins exist are more stable than the Madison or Duck/Cougar creek areas.

Table 2. Winter census records of elk on the Firehole, Madison, Gibbon rivers, 1965-1980.[1/]

	HELICOPTOR		SUPER CUB PLUS GROUND[2/]						
Population Segment	April 1965	March 1967	March 1970	Feb. 1971	April 1972	April 1974	April 1974	Jan. 1980	Mean ±sd
Lower Madison, Duck and Cougar Creek	292	369	--	181	261[3/]	115	219	339	254±89
Upper Madison	52	104	53(119)	56(84)	56(78)	76(67)	81(110)	119(133)	95±27
Gibbon	81	75	23(103)	62(73)	42(76)	--(86)	59(94)	106	87±13
Firehole	307	401	259	359	320	316	282	373	327±48
Totals	732	959	--	697	735	593	705	951	707±137

1/ The data from 1965 to 1976 is from National Park Service files.

2/ Numbers in parentheses are ground counts.

3/ March aerial count.

Classification data presented in Table 3 compares calf and bull ratios per 100 cows for the October-December period to the March-early April periods from 1967 to 1980. The classification data were collected during ground surveys in the Madison, Gibbon, and Firehole Valleys. No data have been collected from the Duck/Cougar creek-lower Madison River segment for this period. The classification breakdown by month for 1979 and 1980 is presented in appendix Table 26. The number of adult bull elk classified during a ground survey on February 29, 1980 yielded 7.5% adult bulls and 2.5% yearling bulls. The number and percent of bulls classified during an aerial flight made on February 28, 1980 is presented in appendix Table 27. The percent of bulls observed in the Duck/Cougar Creek area was much higher than the percent observed in other areas.

Overall mortality appeared to be higher in 1978-79, a severe winter, than during 1979-80, a milder winter. Calf mortality in 1978-79 and 1979-80 was calculated at 62 and 60 percent. In 1978-79, 31 elk carcasses were observed from the air and ground. Twenty-one of these carcasses were examined. The color and texture of bone marrow indicated that all 21 elk died of malnutrition. A cursory examination of rumens in 10 of these elk were made. All 10 rumens were full and consisted a large part of lodgepole pine needles. Of these 21 carcasses examined, 57 percent (12) were calves, 24 percent (5) were old aged cow elk, and 19 percent (4) were mature bull elk. Eighty-one

Table 3. Classification data comparing the October-December ratios per 100 cows to the March-April ratios for the years 1967-1980.

	October - December				March - Early April			
Year	N	Calves	Yearling Males	Adult Bulls	N	Calves	Yearling Males	Adult Bulls
1967	224	43	13	46	--	--	--	--
1968	187	50	15	31	292	22	9	18
1969	176	53	11	39	587	21	9	21
1971	155	50	13	37	318	14	5	15
1972	143	35	5	13	424	35	3	13
1975	189	41	2	15	203	26	6	11
1979	175	50	6	4	197	17	5	4
1980	220[a]	39	2	3[b]	480	16	2	7
Mean ± sd		41±14	8±5	23.5±17		22±7	6±3	13±6

a) Data from January - mild weather in December 1980 prevented classification surveys.

b) Mild December-January weather influenced observability of bull elk. Ground classification on February 29 of 278 elk yielded 7.5% adult bulls and 2.5% spike or yearling bulls.

percent (25) of the 31 carcasses were located during March and April. In 1979-80 only 7 elk carcasses were located during March and April. Five were calf elk and two were old cow elk.

A small amount of movement appeared to occur between the Madison River and Duck-Cougar Creek populations during winters. Very little movement occurred during winter between the Madison and Gibbon or the Madison and Firehole rivers. Narrow steep-walled canyons inhibit movement between these population segments.

Elk used peripheral and core winter ranges as early as November. Concentration onto core ranges by large numbers of elk occurred during the period from mid-December to January in 1978-79. A milder winter in 1979-80 did not concentrate elk populations on core ranges until after January first. Periodic aerial censuses indicated that major movements of large groups of elk onto core winter ranges occurred sometime after snow depth exceeded 60-70 centimeters. During the 2 years of study an average of 108 elk were censused in three flights made prior to snow accumulations of 60-70 centimeters. An average of 355 elk were censused in four flights made after snow accumulations exceeded 70 centimeters but prior to the beginning of snowmelt. Once on core ranges elk movements appear to be restricted by increased snow depth and crusting conditions developing in late January and February. During this period, elk yard up and travel on well established trails. The warm springs, creeks, and rivers are used often as travel lanes as well. Elk dispersed slowly from core winter ranges during late March and April as the snow melted.

The percentage of elk observed in each habitat type occurring along the established snowmobile trail is presented in Table 4. Based on observations of 10,533 elk over a 2 year period, 73 percent were observed in nonforested habitat types. The grassland/sedge type was the most frequently used habitat type. The hot springs-warm ground and willow/sedge types appear to also be used heavily at particular times. The sagebrush/grassland type occurs infrequently within the study area.

Twenty-seven percent of the elk observed during daily reconnaissance of the study area occupied forested types. Elk were observed in six different forest types. The remaining four types occurred in small amounts within the study area and could not be adequately sampled during daily reconnaissance. Because of the small amounts of these types present, elk use of these types could not be determined. Seral subalpine fir types with lodgepole well represented in the stands were commonly used by elk. During severe cold spells when hot springs-warm ground types had been covered with snow and ice, elk browsed the lodgepole needles and twigs for emergency food supplies. Mesic stands of spruce, fir and lodgepole with openings in the canopy sufficient to promote some good understory growth were important also. Dense forest stands of subalpine fir and lodgepole were

Table 4. Habitat types in which elk were observed and percentage of elk observed in each habitat type as determined from ground observations, 1978-80.

Habitat Type	December 78-79	December 79-80[1]	January 78-79	January 79-80	February 78-79	February 79-80	March 78-79	March 79-80	Total
Grassland/sedge	24.3	----	43.5	51.3	50.2	38.3	57.6	48.7	45.9
Hotsprings-warm ground	13.6	----	23.7	10.7	22.2	13.7	14.3	10.6	14.7
Willow/sedge	20.3	----	8.5	7.2	4.3	21.3	2.6	14.5	12.1
Sagebrush/grassland	0.1	----	0.9	0.5	0.2	0.3	0.3	0.1	0.3
Abla/Caru	15.6	----	14.1	17.3	11.9	11.2	8.1	11.5	12.8
Spruce-fir-lodgepole wet forest	12.5	----	5.2	9.2	6.4	12.7	14.4	11.2	10.8
Pico/Cage	1.1	----	3.9	2.6	3.1	2.0	2.0	2.6	2.4
Abla/Cage	0.7	----	----	----	----	----	----	----	0.1
Abla/Vasc h.t.-Vasc	0.6	----	----	----	0.7	----	0.1	----	0.2
Psme/Caru	0.5	----	0.2	1.2	0.1	0.5	0.6	0.8	0.7

[1]No data from December 1979-80 due to absence of snow in this month.

seldom used except during elk movements from one area to another or temporarily for thermal cover. Based on aerial survey and observations of elk sign it appeared that the Douglas-fir type was used extensively at times by elk on the Madison River. This type occurred only on a portion of the Madison winter range and was difficult to record use of by observation methods employed during this study.

A difference in habitat use between years existed. The severe winter of 1978-79 showed increased use of hot springs-warm ground type when compared to the mild winter of 1979-80. Data in Table 4 also indicated that hot springs-warm ground and adjacent grassland/sedge types become most important during the harsher winter months of January and February. The willow/sedge type was more important to elk in the mild winter of 1979-80 than it was during the winter of 1978-79. Increased snow depths and snow conditions appear to regulate the amount of use in this type.

Weather patterns appeared to affect selection of habitat types by elk within the study area. As Table 5 indicates increased use of forested types was made during windy conditions. When temperatures become cold, an increased use was noted for the hot springs-warm ground type. Snow storms in absence of strong winds did cause a significant change in habitat selection. ($P \leq 0.005$).

Table 5. Percent elk observed in each habitat type under prevailing weather conditions, 1978-80.

Habitat Type	Overall Habitat Selection	Wind[1]	Snow[2]	Cold[3]
Grassland/sedge	45.9%	40.2%	43.2%	41.3%
Hot springs-warm ground	14.7	15.3	14.0	22.8
Willow/sedge	12.1	4.7	15.2	15.2
Sagebrush/grassland	0.3	0.3	0.3	0.4
Abla/Caru	12.8	22.9	15.6	11.0
Spruce-fir-lodgepole wet forest	10.8	10.5	7.6	6.0
Pico/Cage	2.4	3.9	3.4	1.5
Abla/Cage	0.1	0.9	0.0	0.5
Abla/Vasc h.t. Vasc	0.2	0.9	0.1	0.3
Psme/Caru	0.2	0.01	0.6	1.0

[1]Winds of greater than 8 km/hr existing as measured with a hand held Wind-o-meter.
[2]Snow is currently falling accumulating more than 2.5 cm not to include small flurries and wind is less than 8 Km per hour.
[3]Maximum temperature is -6.6°C; minimum temperature is below -17.7°C with no wind.

Bison Population Distribution and Habitat Use

The number of bison appearing on winter ranges of the Firehole River has increased since 1967 (Figure 3). The maximum number of bison censused during this study was 868 observed on January 29, 1980. Peak numbers of bison appeared on the Firehole River during March 1978-79 and in January of 1979-80 (Figure 4). Bison were present on winter ranges in December. Movement onto winter ranges of the Firehole were continuous through the winter as snow depth and crust conditions increased in the adjacent Hayden Valley. Some back and forth movement occurs between these two ranges during the winter months.

Table 6 presents the classification data collected during 1978-79 and 1979-80. The percent calves observed in mixed herd groups along the Firehole River decreased as the winter progressed. In February 1980 yearling bison were classified and constituted 9.9 percent of the bison observed.

Bison mortality was recorded in only six instances during the 2 years of the study. Three of these were calves and 3 were adult cows. Four bison died of malnutrition and two calves fell into a thermal pool. The two bison calves were in poor condition before accidentally stepping into the pool.

Bison ranged throughout the core and peripheral ranges of the firehole as delineated in Figure 2. A few bison moved down the Firehole River to winter along the Madison River. Two bison were observed

Table 6. Bison classification in the Firehole River Valley, 1978-80.

Month	1978-79			1979-80		
	Number	% Calves	% Bulls	Number	% Calves	% Bulls
December	93	30	13	--	--	--
January	75	24	3	--	--	--
February	78	18	10	352[a]	27	11
March	--	--	--	209	23	21
April	--	--	--	164	18	17

a) Yearlings equal 9.9 percent of this sample.

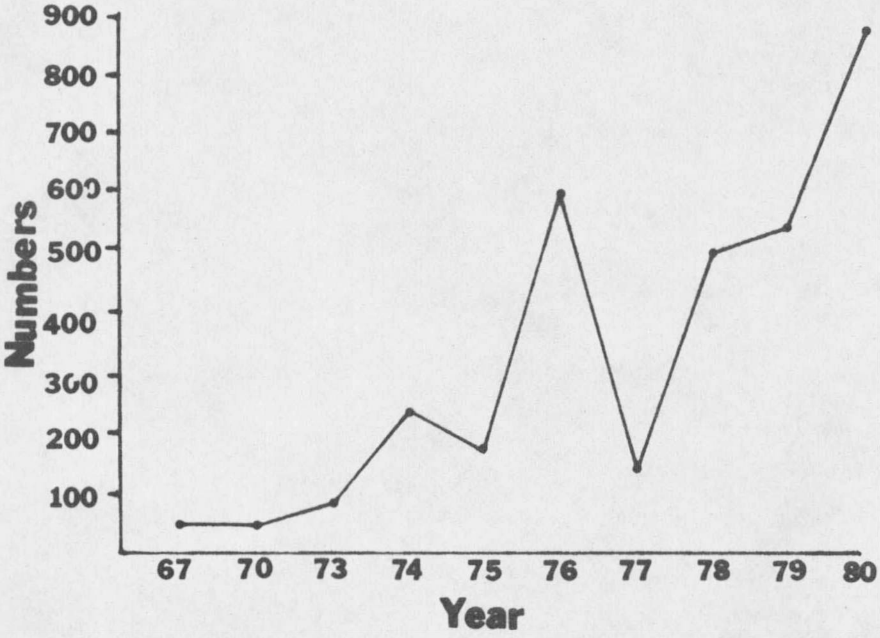

Fig. 3. The number of bison aerially censused in the Firehole River Valley 1967-1980. (M. Meagher, personal communication.) The 1977 count does not represent a population low, only that the bison were in Hayden Valley.

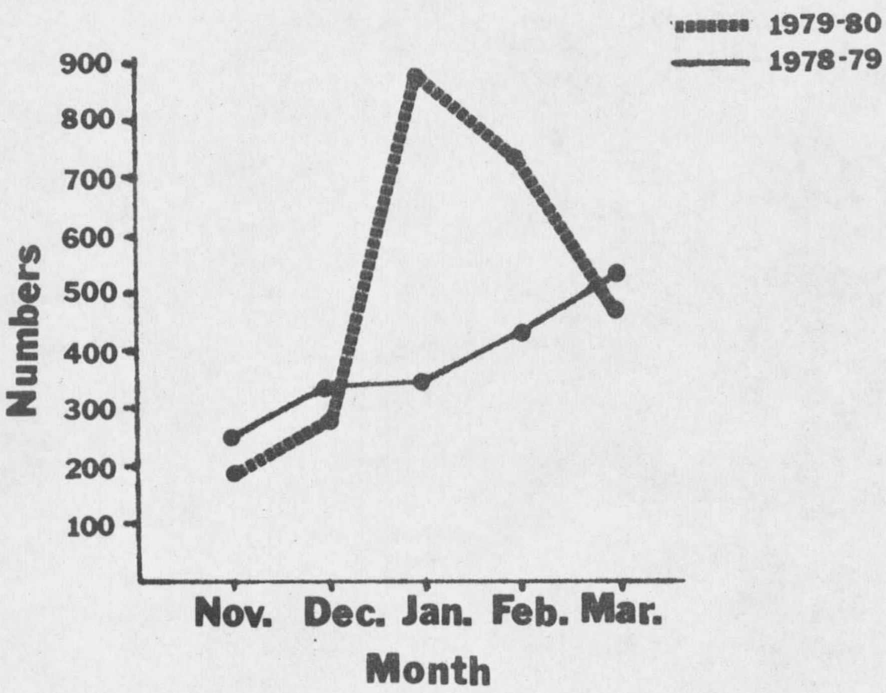

Fig. 4. The number of bison aerially censused each month in the Firehole River Valley 1978-1980. Changes reflect interchange with Hayden Valley.

in the Cougar Creek area during the winter of 1979-80. The largest movement of bison occurred over the Mary Mountain pass from the Hayden Valley and back. Snow depth and weather conditions appeared to be the major factors initiating movement of bison but movement in both direction occurred during the winter.

The percentage of bison observed in each habitat type occurring along the snowmobile trail is presented in Table 7. Of 17,136 bison observations, 89.9 percent occurred in nonforested types. Bison were observed using two nonforested types: the grassland/sedge and hot springs-warm ground types. Bison are able to utilize grassland/sedge types to a greater degree than elk because of their greater ability to forage in deep snow. At least four forested types are utilized by bison, including: wet spruce-fir type, subalpine fir/grouse whortleberry-grouse whortleberry phase (Abies lasiocarpa/Vaccinium scoparium-V. scoparium), subalpine fir/pinegrass (Abies lasiocarpa/Calamogrostis rubescens), and lodgepole pine/elk sedge (Pinus contorta/Carex geyeri). Bison used forested types predominantly for thermal cover or while traveling from one forage site to another. As with the elk, bison appeared to increase use of hot springs-warm ground types during the severest winter months.

Weather conditions also appeared to affect selection of habitat types by bison within the study area. Table 8 indicates that there was a slight increase in use of forested types during periods when

Table 7. Habitat types in which bison were observed and percent of bison observed in each, 1978-80.

Habitat Type	December 78-79	December 79-80[1]	January 78-79	January 79-80	February 78-79	February 79-80	March 78-79	March 79-80	Total
Grassland/sedge	65.0%	----	59.2%	63.7%	50.4%	51.3%	72.0%	53.3%	58.2%
Hotsprings-warm ground	21.9	----	28.9	25.9	39.6	39.4	25.3	31.5	31.7
Abla/Caru	8.2	----	4.4	2.7	5.8	2.1	1.9	6.5	4.0
spruce-fir-lodgepole wet forests	4.3	----	7.4	7.0	2.0	6.9	0.6	7.8	5.4
Pico/Cage	0.0	----	0.1	0.7	1.7	0.3	0.2	0.9	0.6
Abla/Vasc h.t. Vasc	0.6	----	0.0	0.0	0.5	0.0	0.0	0.0	0.1

[1]No data was collected in December 1979-80 due to absence of snow on study area this month.

Table 8. Percent bison observed in each habitat type under prevailing weather conditions, 1978-80.

Habitat Type	Overall Habitat Selection	Wind[1]	Snow[2]	Cold[3]
Grassland/sedge	58.2%	52.2%	48.2%	61.4%
Hot springs-warm ground	31.7	29.6	41.7	28.2
Abla/Caru	4.0	9.4	2.2	3.9
Spruce-fir-lodgepole wet forests	5.4	8.4	6.5	6.4
Pico/Cage	0.6	0.4	0.9	0.1
Abla/Vasc h.t. vasc	0.1	0.0	0.5	0.0

[1]Winds of greater than 8 km/ per hour.
[2]Snow currently falling and accumulating more than 2.5 cm not to include flurries.
[3]Cold - Maximum temperature is -6.6°C; Minimum temperature is below -17.7°C; with no wind.

winds greater than 8 Km per hour prevailed. During periods of heavy snowfall in the absence of wind bison significantly increased use of the hot springs-warm ground type ($P \leq 0.005$). During cold periods bison use did show a significant change in habitat selection compared to their overall selection pattern ($P \leq 0.005$).

Bison movements appeared to be less restricted by snow than were elk movements. A network of well established trails and travel routes were developed as snow depth and crust conditions became severe. Bison frequently used rivers, streams, and warm marshes as travel lanes also. Bison were frequently observed traveling in the packed and groomed snowmobile trail and habitually used the trail as part of their intricate network of trails during winter months.

Distribution and Movement of Other Wildlife

A small herd of 11-13 mule deer ranged in the upper Geyser Basin of the Firehole River. In 1978-79, 62 observations were made while in 1979-80, 134 observations were recorded. Mule deer used the hot springs and forested vegetation types. Only one mule deer was observed north of Biscuit Basin. It ranged with an elk herd in the Madison Junction area in 1979-80.

Moose were observed infrequently in the study area. Four moose were observed in 1978-79 whereas only one was observed in 1979-80. Observations occurred in the upper Geyser Basin of the Firehole River and near the Sevenmile Bridge over the Madison River. All observations of moose were in forested types.

Coyotes occurred throughout the study area. In 1978-79, 18 observations of coyotes were made. During the winter of 1979-80, 39 observations were recorded. The greatest number of observations occurred during middle to late winter as snow depths increased and carrion became more plentiful.

Waterfowl including 10 species of ducks, 3 species of merganser, Canada geese, and trumpeter swans occurred along all the major watercourses within the study area. Six species of ducks were observed to winter on the rivers and streams in the study area. Common goldeneye (Bucephala clangula), Barrows goldeneye (Bucephala islandica), mallard (Anas platyrhynchos), bufflehead (Bucephala albeola), and lesser scaup (Aythya affinis) were commonly observed throughout the winter season. Common mergansers (Mergus merganser) and red breasted mergansers (Mergus serrator) were also frequently observed. Ring-necked ducks (Aythya collaris) and hooded mergansers (Lophodytes cucullatus) were seen infrequently throughout the winter months. In March and April an occasional pintail (Anas acuta), American Widgeon (Mareca americana), green-winged teal (Anas carolininsis), and shoveler (Spatula clypeata) were observed as the annual spring waterfowl migrations began.

An estimated 600-800 Canada geese wintered on the waters of the Firehole and Madison Rivers. These geese concentrated on open waters of the upland thermal sites and small warm water marshes. In spring as the snow began to melt, geese concentrated more heavily on the Firehole River and grazed adjacent thermal sites.

Trumpeter swans wintered primarily along the Madison River but were occasionally observed along the Firehole River as well. In 1978-79 a maximum count of 44 swans was made whereas in 1979-80 as many as 52 were wintering along the Madison and Firehole Rivers. These swans remained from November until late February when all but a few pairs moved down the Madison outside of Yellowstone National Park and to the opening bays of Hebgen Lake and along Henry's Fork.

Bald eagles were commonly observed wintering along the Firehole and Madison Rivers. At least one pair of adult bald eagles has been reported to nest in the Madison Junction area (Kurt Alt personal communication). In 1978-79, 13 eagle observations were recorded and 34 eagle observations were recorded in 1979-80. Two adult eagles and two immature eagles resided in the study area during the winter periods. Observations of eagles in 1978-79 were more frequent on the Firehole River. Eagles were observed feeding on the carrion which was in great supply in this region. Observation of eagles in 1979-80 occurred more frequently along the Madison River; but many observations also occurred on the Firehole. Eagles were observed most frequently in areas where waterfowl concentrated and all but three observations occurred along the Madison and Firehole Rivers.

Tracks, scats, digs, and observations of grizzly bears were recorded during the 2 years of study. Grizzly bears were not frequently active until late March or early April after the winter season has ended and spring thaw arrives. In 1978-79 tracks were observed only once. In the 1979-80 season, tracks were observed three times, one scat was noted, and a dig recorded. Two observations of a female with two yearling cubs were made on the Madison River in 1979-80. At least four different bears had been active in the study area during the March-April period.

Several species of small mammals were present in the study area. However, little data on their current distribution could be collected in this study. During the two years, observations of pine marten (*Martes americana*), beaver (*Castor canadensis*), river otter (*Lutra canadensis*), muskrat (*Ondatea zibethica*), snowshoe hare (*Lepus americanus*), red squirrels (*Tamiascuirus hudsonicus*), longtailed weasel (*Mustela frenata*), porcupine (*Erethizon dorsatum*), and meadow voles (*Microtus pennsylvanicus*) were recorded.

Wildlife - Winter Recreationist Interaction

Wildlife Reaction

The nature and intensity of an animal's response to recreationist and associated activity was influenced by many factors including weather, topography, distribution of vegetation, species behavior, and spatial and temporal distribution of human or related stimulus. In general, a response was placed in one of three broad categories; attention or alarm postures, flight responses, and aggressive responses.

Aggressive responses involving winter recreationists and wildlife were recorded on only two occasions. One incident involved a bison bull which charged a skier and the second involved a large bull elk which threatened a snowmobiler by tooth grinding and antler displays. In both cases the animal was provoked by the close approach of an observer.

Attention and alarm responses varied with the species involved. Mule deer and elk reactions were usually components of the attention and alarm postures described by Geist (1971) and included the directed freeze, strutting parades, forelimb stomping, head elevated movements, and defecation or urination. Bison exhibited the alarm posture as described by McHugh (1958) which often times was accompanied by urination or defecation. A particularly obvious sign of tenseness or excitement in bison was the erect tail. In many instances activities such as shoving, butting and mounting were observed to increase during bison-recreationist interaction, probably as forms of displacement behavior. The directed freeze was an important form of social communication in all species and often resulted in a group response to the stimulus. Coyotes were most likely to flee, but also exhibited attention postures with the head directed toward the disturbance and ears erect.

Flight responses in elk consisted of an alert trot or gallop and occasionally stotting or alert walking occurred. Mule deer flight consisted of bounding. Bison flight consisted of trotting, galloping, or rarely, bounding. Most often the bison flight response was best described as a stampede which involved much bucking and head tossing as the group retreated. Only a few moose were encountered during this study, but when approached, they were reluctant to flee and utilized an alert trot to escape. Coyote flight consisted of walking, trotting, or running, often punctuated by frequent stops. All species had a tendency to stop after a short distance of flight and assume an attention or alarm posture.

Snowmobiler - Wildlife Interaction

Of the 444 total snowmobile-wildlife encounters recorded, 62 occurred during 16 snowmobile trips along the 5.6 kilometer control route. The remaining 382 encounters recorded on the study area were analyzed by time periods. The first period from December 1 to December 15 represented data collected during the winter of 1978 before the opening of the winter season. Only administrative snowmobile traffic was present during this time. The second period from December 16 to January 28 was the coldest portion of winter. The third period from

February 1 until March 18 was a time when snow depths usually exceed 100 centimeters and was a critical time for wintering wildlife.

Snowmobile-wildlife interaction occurred more frequently and the flight response was more prevalent along the control route (Table 9). During the short preseason period from December 1 to December 15, snowmobile-wildlife interaction occurred more frequently than during the snowmobile season. A slight increase in the flight response was observed during the February 1 to March 18 period. This was primarily due to the increased use of the snowmobile trail as a travel lane at a time when mobility was otherwise very much restricted by a deep crusted snowpack. Also, wildlife were concentrated on smaller snow free thermal areas near the snowmobile trail.

Figure 5 shows the daily time periods when snowmobile-wildlife interaction was greatest. The early morning hours and, less so, the evening was when wildlife activity was greatest and also periods when interaction increased. Figure 6 indicates that during the preseason, wildlife interaction occurred more frequently throughout the day. During the preseason period, wildlife appeared to remain active close to the snowmobile trail throughout the midday period as well as during the morning and evening hours. Elk and mule deer were more prone to exhibit diurnal activity patterns than were bison or coyotes. Bison were often traveling, crossing, and even bedded on the groomed trails during the evening or morning hours.

Table 9. A summary of wildlife-snowmobile encounters recorded in Yellowstone National Park during the 1978-79 and 1979-80 winters.

	Number of Encounters	Total Hours	Total Kilometers	Encounters per hour	Encounters per Kilometer	Response percent flight	Response percent alarm
Control Routes	62	14.25	30	4.35	0.68	77.4	22.6
Public Routes December 1-December 15	83	53.50	520	1.55	0.16	54.2	45.8
Subtotal	145	67.75	610	2.14	0.23	64.1	35.9
December 16-January 30	127	152.75	2935.0	0.83	0.04	54.3	45.7
February 1-March 18	172	190.00	3472.6	0.91	0.05	60.5	39.5
Subtotal	299	342.75	6407.6	0.87	0.05	57.9	42.1
TOTALS	444	410.50	7017.6	1.08	0.06	59.9	40.1

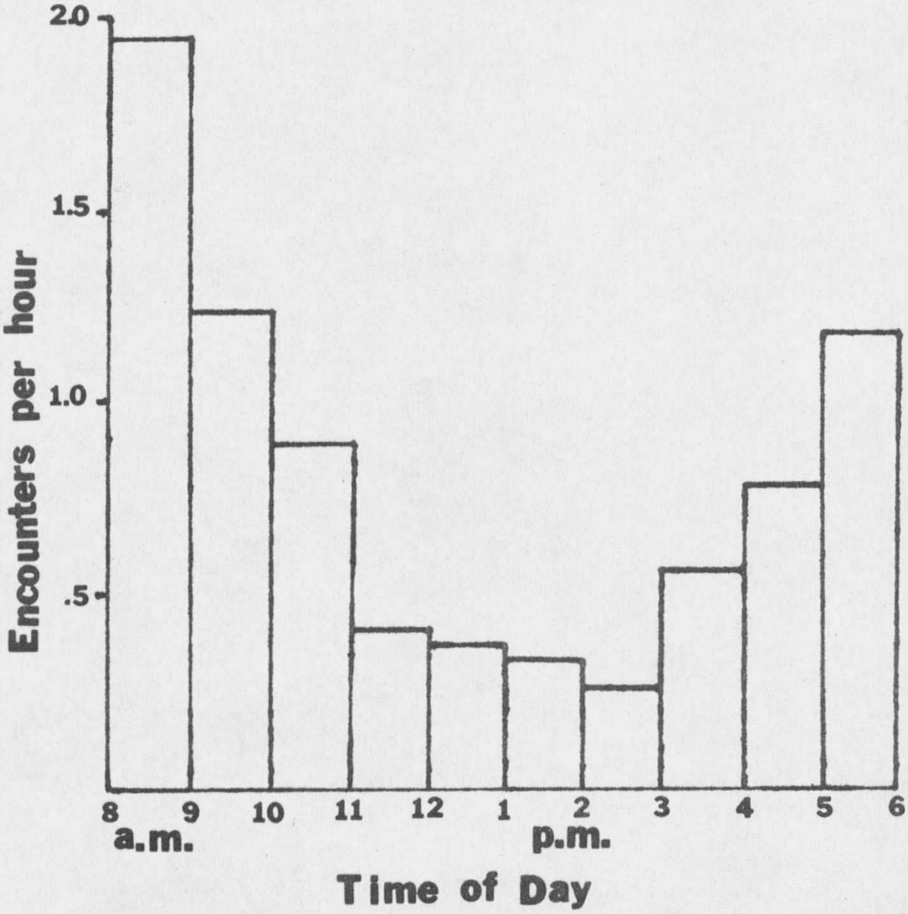

Figure 5. The daily time period distribution of snowmobile-wildlife interactions for all species during the snowmobiling seasons, 1978-80.

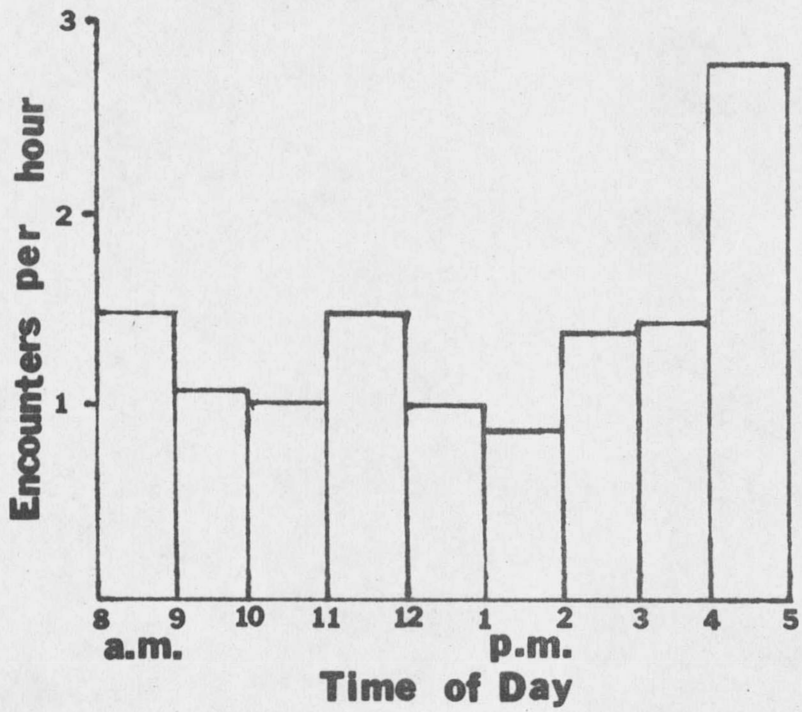

Figure 6. The daily time period distributions of snowmobile-wildlife interactions for all species during the preseason, 1978-79.

Much of the snowmobile-wildlife interaction occurred because of the bison and elk's affinity for the more easily traveled groomed trails and for important wintering areas which were bisected by the trails. Table 10 indicates that bison were more likely to be encountered crossing or traveling on the groomed snowmobile trail than were elk. Both species increased in the percentage of interaction as snow depths increased during the winter. This resulted from the use of groomed trails when snow depth increased during winter. Mule deer and coyotes were often observed crossing the road. On only two instances did I observe a coyote run down the groomed trail when approached by a snowmobile. However, coyote tracks observed after a fresh snow indicated that coyotes used this trail frequently for travel on during hunting forays, but were seldom observed while on the road. In the control area one pass over fresh snow would compact snow sufficiently to support a coyote and use of this trail as a travel lane by coyotes was observed. Bison or elk could not be supported by the compaction of snow after one or even two passes of one snowmobile in the control region. Extensive grooming of the snowmobile trails did compact snow sufficiently to support bison and elk. Sinking depth on the groomed trail was generally less than one inch.

Four instances of wildlife being injured by direct impact with speeding snowmobiles were recorded. Two involved bison, one involved

Table 10. Percent of encounters involving the crossing or traveling of the groomed snowmobile trail by bison and elk in Yellowstone National Park, 1978-80.

Time Period	Bison	Elk
December 1 - December 15	n=8 57.1	n=7 12.5
December 16 - January 31	n=23 71.9	n=22 25.3
February 1 - March 18	n=49 72.0	n=23 25.0

a cow elk, and another was with a coyote which was critically injured while crossing the trail in a heavily timbered area.

<u>Interaction by Individual Species</u>

Snowmobile-wildlife encounters by individual species in the study and the control areas are presented in Table 11. Elk were the most frequently encountered wildlife species followed by bison, coyote, mule deer, and moose. Snowmobile-wildlife interaction was greater for elk, bison, and coyote in the control region than the study area. No mule deer or moose were encountered while traversing the control route. Bison and elk showed a higher rate of interaction during the preseason period when compared to time periods within the snowmobiling season. Bison did increase in rate of interaction during the February and March period when they also showed their greatest propensity to travel on the groomed snowmobile trail. Interaction with mule deer and coyotes were more frequent during the preseason than during the snowmobiling season although sample sizes for both of these species were very small.

Each species varied in sensitivity to disturbance by winter recreational activities. Table 12 indicates that coyotes were the most likely to react to an approach by a snowmobile and to flee in response. Mule deer were second, followed by elk and bison. Mule deer commonly responded to snowmobile activity by fleeing. Elk were most likely to flee in the control area and during the preseason period.

Table 11. Snowmobile-wildlife encounters by individual species for the combined winters of 1978-79, 1979-80.

	Encounters in Control Area			Encounters from Dec. 1-15			Encounters from Dec. 16 - Jan. 31			Encounters from Feb. 1 - Mar. 17			Encounters Total		
	No.	per hour	per km.	No.	per hour	per km.	No.	per hour	per km.	No.	per hour	per km.	No.	per hour	per km.
Elk	47	3.30	.522	56	1.05	.107	87	0.57	.029	92	0.48	.026	282	0.69	.040
Bison	9	0.63	.100	14	0.26	.026	32	0.21	.010	68	0.35	.020	123	0.30	.018
Mule Deer	-	-	-	8	0.15	.015	2	0.01	.001	4	0.02	.001	14	0.03	.002
Coyote	6	0.42	.066	4	0.07	.008	6	0.04	.002	8	0.04	.002	24	0 06	.003
Moose	-	-	-	1	0.02	.001	-	-	-	-	-	-	1	0.01	.000
Total	62	4.35	.688	83	1.55	.157	127	0.83	.042	172	0.91	.049	444	1.08	.063

Table 12. The percent of wildlife encountered responding and percent of these fleeing the approach of a snowmobile during 1978-80.

	Control		Study Area: December 1 -December 15		Study Area: December 16 -January 31		Study Area: February 1 -March 18	
	Percent Responding	Percent Flight	Percent Responding	Percent Flight	Percent Responding	Percent Flight	Percent Responding	Percent Flight
Elk	56.2	75.3	46.8	39.9	12.2	16.2	4.2	16.8
Bison	22.4	89.7	34.6	63.3	4.9	85.5	5.5	81.9
Coyote	100.0	100.0	100.0	100.0	88.8	75.0	83.3	80.0
Mule Deer	--	--	86.9	45.0	23.0	66.6	20.0	50.0
Moose	--	--	100.0	100.0	--	--	--	--

However, during the snowmobile season, elk appeared to habituate to the disturbance created by a snowmobile approach. Bison also responded less frequently to snowmobile approaches after the winter recreation season had begun in the study area. A larger percent of bison-snowmobile encounters resulted in bison fleeing. This was primarily due to the bison's affinity for the groomed trail and the frequent herding of bison down the packed trail by impatient snowmobilers.

The distance at which wildlife is first encountered may influence the outcome of an interaction between winter recreationists and wildlife. Table 13 presents the encounter distances determined for each individual species. For all species combined, the encounter distance along the trail ranged from 9 to 196 meters and averaged 31.2 meters. The average encounter distance for all species combined within the control region was 46.5 meters. Ninety-four percent of the encounters occurred within the 0-60 meter encounter distance range. Coyotes had the longest average encounter distance at 77.3 meters. Elk, bison, and mule deer had very similar encounter distance averages at 29.7, 28.4, and 29.7 meters respectively. Many factors influenced the encounter distance recorded for each species. Topography, spacial distribution of vegetation, restriction of mobility due to deep snow, and behavioral characteristics of the species influenced the eventual outcome of the interaction.

Table 13. The percentage of encounters in various encounter distance categories for each species and all species combined for the winters of 1978-79, 1979-80 combined.

Encounter Distance	Species					
	Elk	Bison	Mule Deer	Coyote	Moose	All Species
0-20 m	37.5% n=88	37.7% n=43	35.7% n=5	-- %	-- %	35.6% n=136
21-40 m	42.5 n=100	50.9 n=58	35.7 n=5	5.6 n=1	100.0 n=1	43.2 n=165
41-60 m	14.9 n=35	9.6 n=4	28.6 n=4	44.4 n=3	--	15.2 n=58
61-80 m	2.5 n=6	--	--	22.2 n=4	--	2.6 n=10
81-100 m	0.9 n=2	1.8 n=2	--	5.6 n=1	--	1.3 n=5
> 100 m	1.7 n=4	--	--	22.2 n=4	--	2.1 n=8

The initial activities wildlife were engaged in upon being encountered were categorized as feeding, resting, alert, ambling, or running (Table 14). Sample size for coyote and mule deer are small, but do appear to reflect some specific behavior differences between the species encountered. Feeding was the most common activity recorded for all species combined and running was the least common activity. Elk frequently were engaged in feeding or resting upon the approach of a snowmobile. Bison were more frequently ambling or feeding upon approach. Bison were recorded as running during 3.3 percent of the approaches; however, all of these incidents involved bison either traveling or crossing the trail in front of the approaching snowmobile. Coyotes were the most difficult species to approach and were commonly ambling, alert, or running when encountered. Mule deer appeared to be more nervous upon approach than either bison or elk and were either ambling, alert, or feeding. The initial wildlife activity observed was frequently influenced by weather, time of day, and intensity of snowmobile activity.

Distance of flight is the observed distance which any animal trotted or ran to escape an approaching snowmobile. The data in Table 15 represents the distribution of distance of flight for each species of wildlife exhibiting this behavior. The distance of flight for all species combined recorded along the trail ranged from 10 meters to 5 kilometers and averaged 37.7 meters. Ninety-one percent of the

Table 14. The initial activities of wildlife encountered by observer during the winters of 1978-79 and 1978-80 combined.

Species	Activity				
	Resting	Feeding	Ambling	Alert	Running
Elk	16.9% n=43	52.9% n=135	16.1% n=41	13.7% n=35	0.4% n=1
Bison	6.5 n=8	23.0 n=28	59.8 n=73	7.4 n=9	3.3 n=4
Coyote	--	--	41.2 n=7	35.3 n=6	23.5 n=4
Mule Deer	--	40.0 n=6	20.0 n=3	40.0 n=6	--
Moose	--	--	--	100.0 n=1	--
All Species	12.5 n=51	41.2 n=169	30.2 n=124	13.9 n=57	2.2 n=9

Table 15. The percentage of distance of flight in each distance of flight category for each species for the combined data from the winters of 1978-79, 1979-80.

Distance of Flight (m)	Species					
	Elk	Bison	Mule Deer	Coyote	Moose	All Species
0-10	18.2% n=20	13.9% n=12	14.3% n=1	-- %	-- %	15.1% n=33
11-50	69.1 n=76	66.3 n=57	85.7 n=6	14.3 n=2	100.0 n=1	65.1 n=142
51-100	10.1 n=11	4.7 n=4	--	57.1 n=8	--	10.6 n=23
100	2.7 n=3	15.1 n=13	--	28.6 n=4	--	9.2 n=20

distances of flight for all species combined were less than 100 meters. The average distance of flight for all species combined within the control area was 50.4 meters. Coyotes had the longest average distance of flight of 90.2 meters. Elk, bison, and mule deer flight distance averaged 33.8, 35.0, and 28.6 meters respectively. Bison had the single longest recorded distance of flight which involved a lone bull herded down the road for 5 kilometers. All the distances of flight greater than 100 meters for bison are a result of snowmobile-bison encounters along portions of the road that bison habitually travel. The distance an animal flees appears to be influenced by weather, time of day, species behavior, recreationist behavior and snow depth or conditions.

Skier-Wildlife Interaction

A total of 54 skier-wildlife encounters occurred during personal ski tours both on and off established trails within the study area (Table 16). The number of encounters per hour recorded during skiing was less than that recorded for snowmobiling, probably a function of the difference in the amount of winter range traversed in one hour by each transportation method. The encounter rate per kilometer skied was greater than per kilometer snowmobiled on established routes. The encounter rate per kilometer while skiing was greater than the encounter rate per kilometer while snowmobiling during the winter on

Table 16. A summary of skier-wildlife encounters in Yellowstone National Park, 1978-80.

	No.	Total Hours	Total Kilometers	Encounters per hour	Encounters per Km.	Percent Flight	Percent Alarm
On Trails	29	50.5	182.0	0.50	0.15	51.7	48.3
Off Trails	25	30.5	110.5	0.95	0.23	72.0	28.0
TOTAL	54	81.0	292.5	0.66	0.18	61.1	38.9

established snowmobile trails; but was lower than the rate per kilometer while snowmobiling in the control region. Interaction per hour or per kilometer was greater while skiing off the established ski trails than when skiing on the established ski trails. The total percent of encounters to which wildlife responded by fleeing was slightly greater for skiing than for snowmobiling. Wildlife responded by fleeing more frequently from a skier skiing off of established trails than from one skiing on established trails. These data suggest that skier-wildlife interaction has a greater potential to occur than does snowmobile-wildlife interaction on established trails during the winter season.

Skier-wildlife encounters by individual species are presented in Table 17. Elk were the most frequently encountered wildlife species followed by bison, mule deer, coyote, and moose respectively. The skier-wildlife encounter rate per hour for each species except mule deer was lower than the rate per hour for snowmobiles. Mule deer-skier encounter rate per hour was higher while skiing than snowmobiling because the small deer herd on the study area ranged in the upper geyser basin where ski trails are concentrated. The encounter rate per kilometer was higher for all species while skiing than when snowmobiling suggesting that potential for interaction was greater for all species concerned.

Table 17. Skier-wildlife encounters by individual species for the winters of 1978-79, 1979-80.

	Number of Encounters	Encounters per hour	Encounters per Kilometer
Elk	27	.33	.092
Bison	17	.21	.058
Mule Deer	5	.06	.017
Coyote	4	.05	.014
Moose	1	.01	.003

Table 18 indicates that coyotes were most likely to react upon approach by a skier and to flee in response. Mule deer were second followed by elk and bison. Only one encounter with a moose was recorded during the study. During the recreation season elk, bison, and mule deer did appear to habituate to skiing activity. In the heavily skied upper geyser basin interaction also appeared to occur less frequently than in areas receiving much less skier use.

For all species combined, the encounter distance ranged from 9 to 180 meters and averaged 45.1 meters. This was significantly greater than the average encounter distances for snowmobiles. Coyotes had the longest average encounter distance of 54 meters. Bison, elk, and mule deer encounter distance averages were 47.7, 43.3, and 38.6 respectively. Eighty-seven percent of the encounters occurred within the 0-60 meter encounter distance range as compared to 94 percent of those for snowmobiles. In general, all species except coyotes appeared to react sooner to an approaching skier than to an approach by a snowmobile on established trails.

The distance of flight for all species combined ranged from 10 meters to 0.8 kilometers and averaged 114.5 meters. The average distance of flight for all species combined was much greater for encounters with skiers as compared to encounters with snowmobilers. Eighty-five percent of the distance of flight for all species combined were less than 100 meters. Bison had the greatest average distance of

Table 18. Percentage of animals observed which responded to skier approach and percent of these animals which exhibited flight response during the winters of 1978-79, 1979-80.

	Percent Responding	Percent Flight
Elk	39.3 n=133	82.0 n=109
Bison	37.0 n=183	43.2 n=79
Mule Deer	45.9 n=17	88.2 n=15
Coyote	71.4 n=5	100.0 n=5
Moose	100.0 n=1	100.0 n=1

flight recorded at 248.5 meters. Coyote, mule deer, and elk followed with average distances of flight at 63.0, 53.3, and 52.4 meters respectively. Bison exhibit a unique tendency to respond dramatically to skier approaches off the established trail. In two instances, stampedes were induced by an approach to bison while on skis. On the average, all species would flee further from a skier than from a snowmobiler.

Classification, Distribution, and Intensity of Use

There are three principle categories of winter recreationists traveling within Yellowstone National Park during the winter months. These are: visitors on foot, skiis, or snowshoes, visitors on private oversnow vehicles, and concessioner snowcoach passengers. Table 19 presents summary records of winter recreation use from 1966 through March 1980 provided by the Visitor Services Center of the National Park Service. Winter visitation during 1980 reached an all time high. The types of recreation use the park receives has changed significantly during this period. The number of private snowmachines entering the Park appears to have stabilized since 1972 and ranges between 26,000 and 30,500 snowmachines per year. Skiers and snowshoers entering through Park gates have declined severely over the last 3 years while the number of snowcoach passengers has increased tremendously during that same period.

Table 19. Summary of winter recreation use in Yellowstone National Park 1966-1980.

	Skiers and Snowshoers	Concessioner Snowcoaches	Snowcoach Passengers	Private Snowmachines	Number of Snowmobilers	Total Visitors
1966-67	no record	349	3,045	1,544	2,173	5,218
1967-68	no record	748	4,359	2,352	3,425	7,784
1968-69	10	728	4,249	4,726	6,076	10,335
1969-70	191	504	4,238	8,206	10,978	15,407
1970-71	206	625	5,241	11,614	14,188	19,635
1971-72	388	679	5,529	17,436	20,271	26,188
1972-73	931	602	3,846	26,826	31,774	36,551
1973-74	2,445	698	4,425	30,513	36,655	42,525
1974-75	3,869	776	5,537	26,400	30,763	40,169
1975-76	4,536	774	6,300	25,163	31,041	41,867
1976-77	5,724	508	3,659	20,476	25,722	35,105
1977-78	3,806	935	6,822	26,563	35,784	46,412
1978-79	1,571	1,087	10,211	24,947	32,810	44,592
1979-80	986	1,867	15,043	27,691	34,810	50,839

Oversnow Vehicular Use

Data in appendix Table 28 indicate that a large percentage of Yellowstone Park winter recreationists enter the park through the west and south entrance gates. Most of these recreationists are bound for the Old Faithful Village. From a Yellowstone National Park Service survey taken verbally at Westgate of 200 snowmobilers, 85% were going to Old Faithful, 7% were going to Canyon Village, 4% were destined for the east gate entrance, and 4% were going to Mammoth. West and South gates also receive snowcoach traffic with most trips destined for Old Faithful Village (Appendix Table 29). An average of 20.5 snowcoaches per day passed into the park by these two entrances in the 1979-80 winter season.

Snowmobile activity varies a great deal from day to day. Figure 7 graphically depicts the weekend pulses of oversnow vehicles entering through West gate entrance station. The Christmas and Washington's birthday holidays are two periods receiving heavy snowmobile use. During this study, the largest number of snowmachines recorded on any single day by a photoelectric eye placed in the Old Faithful Village was 757 on February 16, 1980, the Washington Birthday holiday. The highest number of machines passing through the West gate entrance was 738 reported on February 17, 1979. The month of February receives more oversnow vehicular use than any other month. This is the month

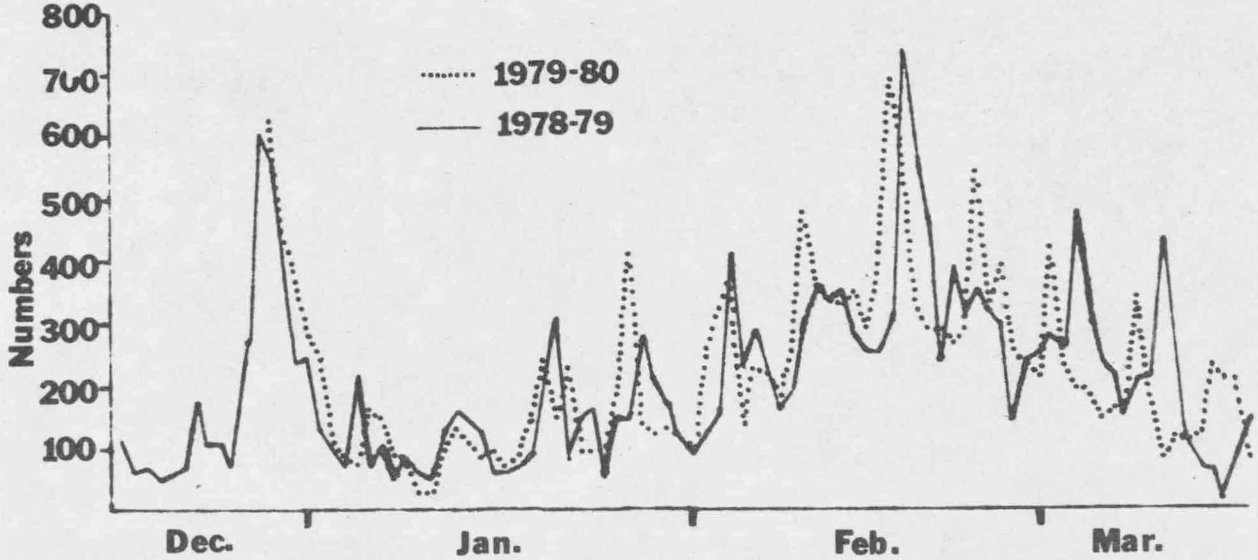

Figure 7. Daily numbers of snowmachines entering through the West gate entrance to Yellowstone National Park. 1978-80.

when snow conditions are good and the prevailing weather pattern is conducive to winter sports such as snowmobiling.

Snowmobile activity exhibits a diurnal pattern. In the Old Faithful Village most snowmobile activity occurs between the hours of 10:00 a.m. and 4:00 p.m. (Figure 8). This can vary according to the length of daylight to a slight degree. The daily pulse of activity at Old Faithful Village has its peak between 12:00 and 3:00 p.m. In the West gate entrance area snowmobile activity occurs throughout the daylight hours. There are, however, two prominent peaks in activity at West gate entrace correlating with the visitors entering and leaving the park (Figure 9).

Snowmobilers traveling through West gate entrace are generally interested in scenic views, wildlife, and the sport of snowmobiling itself. Most winter travelers do not remain overnight, but make day trips into the park. Table 20 presents user data collected during a questionnaire card survey conducted by the Yellowstone Park Service during 1978-80. Only a 5.7 percent of snowmobilers reported participating in skiing or snowshoe activity.

Skiing and Snowshow Use

There are approximately 80 kilometers of established snowshoe and ski trails in the Geyser Basins of the study area. Most of the skier and snowshoe use within the study area was concentrated on trails

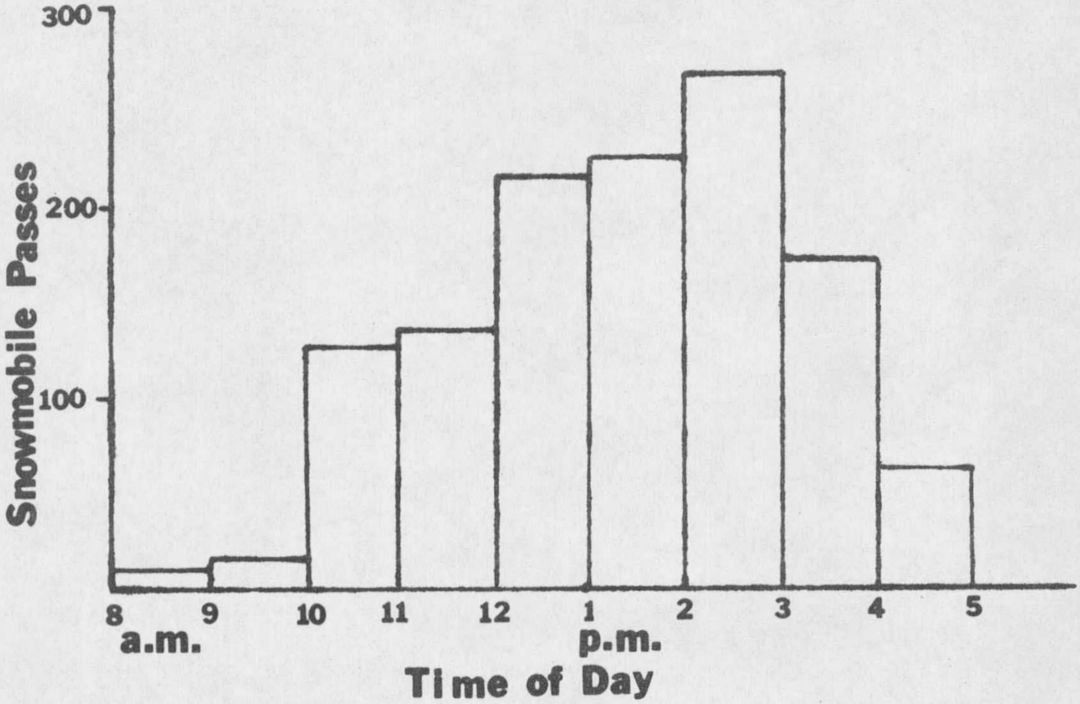

Figure 8. Number of snowmachines passing through the photoelectric eye counter at Old Faithful during each hour of the day for February 16, 1980.

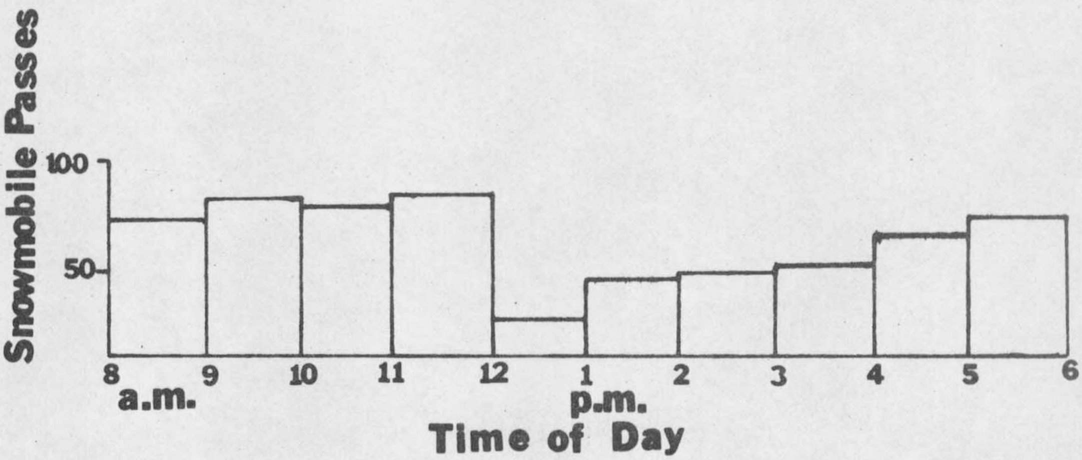

Figure 9. Number of snowmachines passing through the west entrance station during each hour of the day for February 18, 1980.

Table 20. Summary of activity and party size data collected during Yellowstone National Park snowmobile survey, 1978-80.

	1978-79	1979-80
Kilometers traveled within the Park	215.4	409.8
Percent remaining overnight	13.0	22.6
Average machines per party	5.5	6.6
Average people per party	6.1	7.5
Percent participating in skiing or snowshoeing	1/	5.7

1/ No data. Question not asked in the 1978-79 survey.

emanating from the Old Faithful Village. The heaviest concentration of skiers occurred in the Upper Geyser Basin. The largest percentage of skiers directed their efforts to short day trips to view the scenic geothermal features of the park.

Intensity of ski and snowshoe use varies from year to year depending on snow conditions. In 1979-80, the late appearance of snow delayed the opening of the winter season by one week as compared to 1978-79. Late March storms extended the active ski season in 1979-80. The daily record of the number of skiers registered at Snowlodge in the Old Faithful Village is presented in Figure 10. The weekend pulses and overall use trends were similar to those of oversnow vehicles. February was the heaviest use month. Records from Snowlodge indicate that an average of 101.3 skiers were checked in per day over the 1978-80 period with a range of 34 to 179 skiers present. The maximum number of skiers registered at Snowlodge for the two winters was 179 on December 25, 1978.

Two major trails, Lonestar Geyser and the Fairy Falls trail, had photoelectric eye counters placed at the trailheads during the months of January, February, and March in 1979. The data from these counters are presented in Table 21. Lonestar Geyser trail received an average of 12.9 skiers per day during this period while the Fairy Falls trail averaged 14.5 skiers per day.

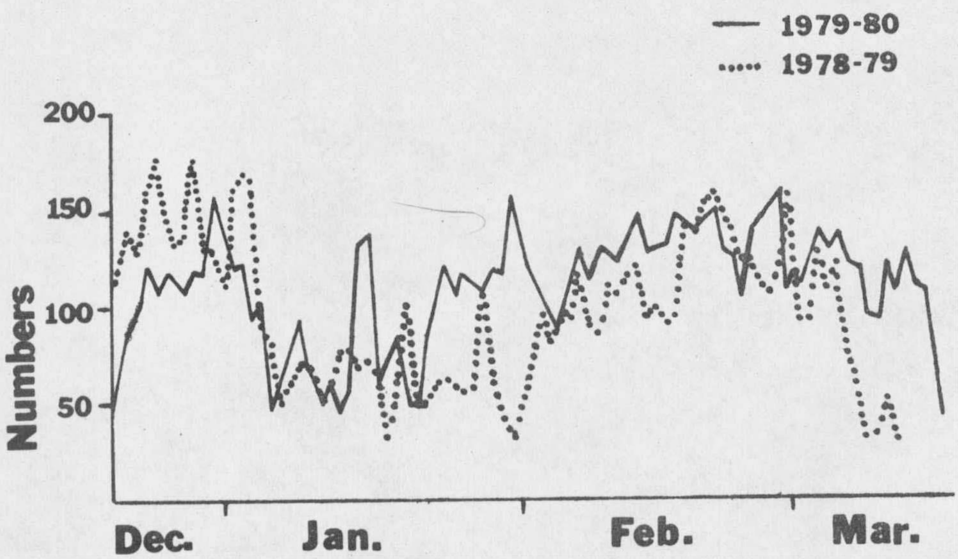

Figure 10. Daily numbers of skiers registered at Snowlodge 1978-80.

Table 21. The number of skiers using two ski-trails as determined by photoelectric eye counters for the months of January, February, and March 1978-79.

	Lonestar Geyser		Fairy Falls	
	Number	Daily range	Number	Daily range
January	249	0-30	231	0-40
February	525	1-64	681	2-70
March	206	2-28	186	1-49
TOTAL	980	0-64	1,098	0-70

Backcountry use data were collected from the use permits issued at Old Faithful Visitor Center for the 1979-80 winter season. During the period from December 17th, 1979 to March 23, 1980 a total of 128 backcountry use permits were issued. Three hundred and eighty three visitors camped out for 393 nights and averaged 3.07 nights per visit. Appendix Table 30 gives the number of camp-nites spent at each of several designated sites. Winter campers from Old Faithful Village focused most of their effort in the Upper Firehole, Shoshone Lake, and Bechler River direction. Many camp-nites were spent in camp-sites within the Old Faithful Village itself.

Recreationists Effects on the Winter Environment

Air Pollution

An attempt was made to determine if snowmobile exhaust emissions have increased lead levels in the air. Early attempts using low volume air sampling techniques yielded no results and a more sensitive technique utilizing atomic absorption was then employed. The atomic absorption technique showed some promise but during this study yielded no conclusive results. A number of difficulties were encountered, most of which resided with the sampling procedure. The technique was sensitive enough that contamination of the samples became a serious problem. Many samples were collected but yielded no data until the sampling process was refined toward the end of the winter season 1980.

Table 22 presents data collected on March 16, 1980 at Old Faithful, when air samples were collected each half-hour.

Snow Pollution

Determinations were made of lead and dissolved organic carbon levels in snow samples taken weekly in January and February of 1980. Results of analysis for organic carbon are presented in Table 23. A great deal of intra-sample variation existed in the results and significant conclusions cannot be clearly drawn. Samples taken adjacent to the groomed trail and from the groomed trail had a greater range in concentrations and a higher maximum value than samples taken in a control area and samples taken 30 meters distance from the trail.

Lead levels determined in snow samples by atomic absorption techniques are presented in Table 24. Again, the range of lead concentrations and the mean levels of lead were greater for samples taken adjacent to or on the groomed trail. Mean lead level in the control region did not differ significantly from the mean level at 30 meters from the trail ($P \leq 0.05$). There appears to be a build up of lead in the snow from January until mid-February followed by a decline in the concentrations of lead in the samples taken in late February.

A sample of the entire snow column was taken in April, 1980 to determine if a lead build up had occurred. Table 25 gives the results of the lead determination in each of the 5 cm segments of the snow column. In the sample taken trailside, portions of the column had

Table 22. The daily fluctuation in atmospheric lead levels as indicated by air samples taken March 10, 1980 at Old Faithful Village.

Sample Number	Time	Concentration Pb ng/m^3	Winds	Number of Machines Operating	Number of Machines Parked
5	10:00 A.M.	4,900	Calm	2	15
6	10:30 A.M.	4,500	<5mph	2	13
7	11:00 A.M.	4,100	<5mph	9	25
8	11:30 A.M.	3,400	<5mph	8	30
9	12:00 Noon	3,200	3-6mph	9	30
10	12:30 P.M.	2,900	5-8mph	4	50
11	1:00 P.M.	11,100	5-8mph	8	51
12	1:30 P.M.	6,300	8-12mph	7	93
13	2:00 P.M.	4,400	6-8mph	5	95
14	2:30 P.M.	6,100	6-8mph	8	59
15	3:00 P.M.	3,200	8-10mph	13	43
16	3:30 P.M.	1,800	8-10mph	2	25
17	4:00 P.M.	1,900	8-10mph	0	18
18	4:30 P.M.	2,500	5mph	8	15
19	5:00 P.M.	2,300	Calm	3	11

Table 23. The concentrations of dissolved organic carbon in snow samples taken in Yellowstone National Park along the West gate to Old Faithful snowmobile route, 1979-80.

	Control Area (ppm)[1]	30 Meters From the Trail (ppm)	Trailside (ppm)	On the Trail (ppm)
January 13	2.35-6.20	1.23-2.05	1.50-2.30	1.60-2.70
January 20	0.84-1.70	2.60-4.76	1.60-3.76	4.95-6.85
January 27	1.15-5.68	2.12-5.63	2.65-3.86	3.20-4.57
February 3	2.92-4.55	1.43-1.62	3.35-12.80	1.96-2.30
February 20	1.81-3.77	2.39-4.62	1.40-1.80	2.67-10.70
Overall Range	0.84-6.20	1.23-5.63	1.40-12.80	1.60-10.70

1/ppm = parts per million

Table 24. The concentrations of lead in snow samples taken in Yellowstone National Park along the Westgate to Old Faithful snowmobile route.

	Control Area (ppb)	30 meters from the trail (ppb)	Trailside (ppb)	On the Trail (ppb)
January 13	8.5	9.0	7.5	57.0
January 20	3.5	7.0	16.0	26.5
January 27	2.5	1.5	47.0	84.0
February 3	5.0	5.0	51.5	90.0
February 10	7.5	3.5	18.0	316.0
February 20	T	T	20.0	110.0
February 28	T	T	7.5	35.0
Mean	3.9	3.7	23.9	102.6
Range	0.0-8.5	0.0-9.0	7.5-51.5	26.5-316.0

Table 25. Concentration of lead in samples of the snow column taken in April 1980 along the West gate to Old Faithful groomed snowmobile route.

Depth (Cm)	Roadside (ppb)	30 Meters from Trailside (ppb)
0-5 cm	<5.0*	<5
5-10	20.0	T
10-15	35.0	T
15-20	300.0	T
20-25	T	<5
25-30	15.0	T
30-35	42.5	T
35-40	<5.0	<5
40-45	T	T
45-50	<5.0	T
50-55	T	<5
55-60	10.0	<5
60-65	150.0	<5
65-70	<5.0	<5
70-75	7.5	T
75-80	5.0	**

* Concentrations of less than 5.0 ppb are less accurate so were reported as <5.0.

** Snow depth varies by 5 cm at the sample sites.

heavy lead concentrations while other layers had low lead concentrations. The sample taken 30 meters from the trail had low lead concentrations throughout the column.

Noise, Litter, and Physical Damage to Soil and Plants

Other impacts associated with winter recreationist activities were recorded in general observations. Noise was one impact of sufficient influence to be worthy of comment. Noise produced by oversnow vehicles could be heard throughout most days of the active winter season. On good calm days, noise from snowmobiles could be heard from Mallard Lake a distance of 3.6 airline km from the groomed trail. On most days, noise was easily heard from 1.6 km distance. Noise levels in the west gate entrance and Old Faithful Village were greater than along the trail.

Litter was an observable problem along the trails and at all recreation facilities. Perhaps 200 incidences of litter a year were observed and most involved such items as beverage cans, candy wrappers, film containers, worn snowmobile parts, and frequently the pamphlets or maps handed out at park entrance gates. Sufficient numbers of trash cans were available along the groomed trail to prevent most cases of littering if used.

Physical damage to soil and plants by snowmobiles was observed during the 2 years of this study. Most damage was a result of illegal sidehilling along the trail. Occasionally flagrant violators left the trail and traversed into open meadows as well. During the spring, as snow begins to melt, detours developed around exposed pavement of the road beneath the trail. These detours often caused soil and plant damage and accelerated erosion at such sites in the spring. In most instances, soil and plant damage was restricted to small localized areas.

DISCUSSION AND CONCLUSIONS

Recreation Activity and Wildlife Distribution, Movement, Cover Use

Recreation activity was not a major factor influencing wildlife distribution and cover use. However, the human disturbance created by a winter recreation program within this portion of Yellowstone National Park has imparted some subtle effects on wildlife distribution and movement. The principle factors determining selection of cover types and the distribution of wildlife was the location of food coupled with minimizing the energy demand of the environment.

Wildlife did not distribute themselves randomly throughout the 18,688 hectares of winter range. A great number of animals focused on the geothermally active basins and along rivers and streams. The concentration of wildlife onto 5,608 hectares of core winter range was a response to the minimal energy demand and a greater availability of food on these areas. Craighead, et. al. (1973) observed that the elk could not winter near Norris or Old Faithful if it were not for the small, relatively snow-free thermal areas and warm streams that alter the winter environment by furnishing both travel lanes and feeding sites. Meagher (1970) reported on the importance of thermal sites to Bison wintering along the Firehole River. The concentration of herbivores attracts secondary consumers into these areas as well.

Recreation activity was also focused in these thermally influenced basins and along rivers where spectacular scenery, wildlife and unique geologic phenomenon could be observed. As a result, the ski and snowmobile trails transect critical sites upon which wildlife are dependent for their survival. Observations of wildlife responses to human activity within the study area indicated that occasionally heavy traffic on these trails inhibited free movement of animals and temporarily displaced wildlife from areas immediately adjacent to the trails. Cole (1978) noted the displacement of elk along the trails during periods of fairly continuous travel by snowmobiles in the Madison and Firehole River Valleys of Yellowstone National Park. In Minnesota, Dorrance, et. al. (1975) concluded that white-tailed deer were displaced from areas immediately adjacent to snowmobile trails receiving light use. Neuman and Merriam (1970) report that activity data for snowshoe hares indicates that these browsers do avoid snowmobile trails.

The area where disturbance had its most significant impact on wildlife distribution was within 60 meters distance from the trail. Neuman and Merriam (1972) found that the disturbance of snowshoe hares (Lepus americana) by snowmobiles was mainly within 76 meters of the snowmobile trail. The overall area affected along snowmobile and ski trails within the core winter ranges was approximately 972 hectares or 17 percent of the total core range. Displacement from this area could be detrimental to the survival of wildlife.

The trails that exist within core winter ranges did not appear to be a barrier to wildlife movement. However, observations indicated that during periods of heavy traffic, wildlife movement across the trails to preferred grazing areas may be inhibited. Ward, et. al. (1973) reported telemetered elk appeared cautious about crossing major roads. Singer (1975) reported that highway crossings by mountain goats were affected by the pattern, amount, and location of traffic and visitor activity. Traffic on the groomed snowmobile trail into Old Faithful Village occasionally exceeded 90 machines per hour, and the grooming operation to prepare the trail created a berm up to 1 meter high. Both traffic and the berm created by grooming inhibited crossing of the road and artifically concentrated wildlife. Observations confirm that elk, bison, and deer appeared to prefer crossing the trail where the berm is absent or reduced and when traffic was reduced.

The degree to which human disturbances actually affected movement and distribution of wildlife was minimized by habituation of animals to traffic and adjustments in their activity patterns. Evidence collected during this study indicated that mule deer, elk, and bison habituated to snowmobile and ski activity. All three species were observed to reduce intensity and frequency of reactions to recreation activity progressively during the first two weeks of exposure to human disturbances. The young of the year age class exhibited the most pronounced change in reactions. Cole (1978) reported on the habituation of elk to snowmobiles in Yellowstone National Park. Richens and Lavigne (1978) found that white-tailed deer in Maine habituated to judicious use of snowmobiles. Young and Boyce (1971) stated that "Deer can even become conditioned to the sound of snowmobiles in anticipation of food. However, this is not true of some more endangered species such as wolf, elk, coyote, bobcat, and bald eagles."

Geist (1971) stated that, "Mammals learn to minimize encounters with humans if harassed enough by reducing activity to areas, habitats, and times of day where encounters with humans are minimal." Data indicate that wildlife in the Madison and Firehole River Valleys of Yellowstone National Park adjusted their daily activity routine to minimize encounters with winter recreationists. A crepuscular activity pattern became more pronounced during periods when snowmobile traffic was heaviest. Andrews (1979) indicated that such a shift in "time territories" may be a mechanism for reducing stress in behavioral interactions. The morning and evening periods of wildlife increased activity overlapped only slightly with the human activity periods. It was during these morning and evening periods when interaction between humans and wildlife was greatest. All species appeared to become more active nearer the trails during these periods ensuring that essential winter range was utilized. Schultz and Bailey (1978) noted that elk in Rocky Mountain National Park, Colorado minimized encounters with humans by their crepuscular habits and winter use of areas near buildings during night hours. Dorrance, et. al. (1975) reported deer returning to areas along trails within hours after snowmobiling ceased at St. Croix State Park in Minnesota.

Wildlife movement was modified by recreation trails when wildlife used these trails as travel lanes during the winter. The groomed snowmobile trail between West Yellowstone and Old Faithful Village was used as a travel lane by wildlife in the basins. Trail use became more prominent as off trail mobility decreased and snow depth increased. Ski trails except in the Upper Geyser Basin were of no advantage to traveling wildlife so were seldom used as travel lanes. Wanek (1971) points out that two passes with a snowmobile is equivalent to 50 "people passes" on snowshoes. Based on this data only a few ski trails would receive sufficient travel each day to compact the trail enough to provide easier mobility to elk, mule deer, or bison. Coyotes, however, can be easily supported on ski trails through the winter range and were observed to use them. Bison incorporated the groomed snowmobile trail into the complex network of trails habitually traveled during the winter. Elk occasionally used snowmobile trails as a travel route when snowmobile traffic ceased. Coyotes used the groomed snowmobile trail during night hunting forays but avoided the trail during the days. Neuman and Merriam (1972) found that red fox activity was greater close to the same snowmobile trail that snowshoe hares avoided. Richen and Lavigne (1978) reported that white-tailed deer travel and feed along snowmobile trails made in openings adjacent to existing concentration areas in Maine.

The Effects of Recreation Activity on Wildlife Populations and Energetics

Cole (1978) hypothesized that increased disturbances created by recreation use in the study area could have the same ecological effects as harsh weather that increased energy expenditures, or competitors that reduced space or food. Permanent reductions in space or food could conceiveably lower ungulate populations which would also reduce food for predators and scavengers. Census information obtained from 1967 to 1980 seems to suggest that the present levels of human use were not causing a downward trend in the elk population (Table 2). Winter census records of bison in the Firehole River from 1967 to 1980 indicated bison numbers have actually increased (Figure 3). Meagher (1970) and Cole (1978) suggested that population regulation in these ungulates was due to density-influenced intraspecific competition for space, food, or mates (males only) and the additional effects of periodic harsh weather.

No population data existed regarding wildlife species other than elk and bison. However, from observations it appears that mule deer, moose, and coyotes could not have been severely affected by increased recreation activity since 1967. Populations of rare, endangered and sensitive species are most likely to be influenced by human disturbance. No evidence of wolf, wolverine, or mountain lion activity was recorded during this study. It is possible that winter recreation activity may prevent occupation of critical habitat for sensitive species such as these. The core winter areas contain sufficient prey and abundant carrion but lack the necessary isolation required by populations of these sensitive predators and scavengers.

It does appear that recreation activity has increased energy expenditures of wildlife in Yellowstone Park. During the critical winter period increased excitement caused by human disturbance can create significant additional energy expenditures. Excitement is costly because it elevates metabolism (Graham in Blaxter 1962). Geist (1971) calculated that mild excitement of a ruminant such as caribou or sheep during which the animal does not run, costs about 25-30 kilocalories $kg.^{0.73}$ per 24 hours or 1.0-1.4 kilocalories per $kg.^{0.73}$ per hour above and beyond normal daily expenditures. Exertion such as fast, sustained running by well trained animals costs about 1,400 kilocalories $kg.^{0.73}$ per 24 hours or nearly one kilocalorie $kg.^{0.73}$ per minute. This additional energy expenditure could be particularly significant to the growing young of the year, to pregnant females, and animals in poor condition. However, no statistically significant correlations could be demonstrated between elk calf survival or loss and amounts of recreational use.

Ungulates in the study area habituated to the human disturbances created by recreation activity and thus reduced the physiological cost of winter survival. Reaction intensity and frequency decreased as the winter progressed reducing the overall negative effects of disturbances on energy budgets of these animals. The most significant expenditures of energy created by recreationists occurred during interaction along the groomed snowmobile trail and when photographers moved up for a closer shot.

Wildlife Response to Recreation Activities

The nature and intensity of an animal's response to recreationists and associated activity was influenced by many factors including weather, topography, distribution of vegetation, species behavior and the spacial or temporal distribution of human disturbance. The most intense reactions involved flight behavior but a host of stationary alert responses were also observed. Aggressive responses were rare and restricted to incidents where the animal was approached intolerably close.

Bollinger et. al. (1973) doubted that deer response to snowmobiles was due to noise alone. His results indicated that snowmobiles need to be within sight before the animal will react by moving away. In Yellowstone Park it appeared that visual stimulus of a moving snowmobile or skier was the primary stimulus initiating the flight response of ungulates. Ungulates did respond to the noise of snowmobiles and skiers when first arriving at the winter range but habituated to the noise. Other authors have reported such habituation to noise (Dorrance, et al. 1975, Houston 1976, Cole 1978, Meagher 1970, Schultz and Bailey 1978, Geist 1971, Singer 1975, and Ward, et al. 1973). An early account of habituation to noise by mule deer in Yellowstone Park is presented in Osborne Russell's Journal (Ed. by Haines 1965). In the summer of 1839 he visited the park and said, "Vast numbers of black-tailed deer are found in the vicinity of these springs and seem to be very familiar with hot water and steam, the noise of which seems not to disturb their slumbers, for a buck may be found carelessly sleeping where noise will exceed that of three or four engines in operation." Habituation to winter recreation activity in Yellowstone Park takes place within the first 2 weeks of the winter season.

Wildlife react more intensely to an approaching skier than to an approaching snowmobile. Walther (1968) observed that Thompson's gazelles reacted sooner to a man on foot than to a car. Schultz and Bailey (1978) observed longer flight distances for an approaching person than for a vehicle suggesting elk were more sensitive to the former. Richens and Lavigne (1978) stated that deer tend to run with the approach of a human on foot, in contrast to their tendency to stay in sight when approached by a snowmobiler, suggesting that the deer responded to the machine and not to the person riding it.

In general, an animal strives to live and function best in a predictable physical and social environment (Geist 1970). The disturbance that is most detrimental is one that is frequent and unpredictable so that the animal cannot escape it. Snowmobile traffic in Yellowstone Park was predictable and localized in time and space whereas ski traffic was less predictable and not as localized. Skiing in the Upper Geyser Basin where trail restrictions are imposed creates a more predictable environment and wildlife have habituated to the activity here. However, in other areas ski use was not restricted to trails and resulted in frequent, intense interaction which could be detrimental to wildlife.

Altman (1958) noted a seasonally changing threshold of sensitivity to disturbance in elk and moose due to reproductive and nutritional status. Encounter distances reported in this study ranged from 9-196 meters and were less than distances reported by Chester (1976) for similar species studied during summer months in Yellowstone National Park. Schultz and Bailey (1978) recorded flight distances of wintering elk in Rocky Mountain National Park, Colorado. They reported flight distances ranging from 19-308 meters. Apparently the nutritional status and demanding winter environment increases the tolerance threshold of wildlife to human disturbances. Richens and

Lavigne (1978) reported that most deer encountered by a snowmobile ran from sight in December and January but tended to remain within sight during February, March, and April. They suggested these differences in deer escape behavior were associated with a progressive weakening of their physical condition through the winter. These same authors reported that when snow depths exceeded 92 centimeters more deer stayed than ran when encountered on snowmobile trails. In Yellowstone Park I observed similar tendencies in the species of ungulates studied. Elk, mule deer, and bison reacted less frequently, were more easily approached, and would flee for only short distances as the winter progressed and snow depths restricted mobility.

Topography and cover were two factors which seemed to influence wildlife reactions. The location of a visual barrier or some physical barrier such as a river or stream often affected the outcome of an encounter. Wildlife were approached more closely and tolerated human disturbance when a river or some vegetative cover stood between themselves and the source of disturbance.

The behavior of recreationists can affect the reaction of wildlife to disturbance. People stopping snowmobiles and getting off to approach closer to wildlife caused them to flee. Skiers off the established trails induced intense wildlife reactions especially in bison which frequently stampede when approached. Schultz and Bailey (1978) reported that elk would flee when people left roads to approach the animals. Richens and Lavigne (1978) reported that snowmobiling at high speeds frightened deer more easily than at low speeds (16 kilometers per hour or less), but stopping to view deer invariably resulted in their flight. Also more deer ran when approached directly than when approached obliquely with a snowmobile and deer were more easily frightened when observed by looking directly at them than when not.

Threatened or Endangered Species

Grizzly bear, bald eagle, and trumpeter swan were three threatened or endangered species of wildlife observed during this study.

Grizzly bears and grizzly bear sign were observed in this study during the March-April period after bears emerged from their dens. No bear activity was recorded during the winter snowmobile season. Winter recreation prior to mid-March probably does not have much impact on grizzly bears. However, extension of the winter recreation season beyond mid-March could impact bears by displacing bears from carcasses available along roadsides. One sow and two yearling cubs were observed to be displaced from a cow elk carcass by motorists on the road during April of 1980. Singer (1975) suggested that grizzly bears in Glacier National Park avoided the highway area. Cole (1978) and Houston (1978) found that elk carcasses adjacent to roads or facilities used by humans remained intact longer.

Bald eagles were observed both winters of the study along the Madison and Firehole Rivers. Eagles were also displaced from elk carcasses by recreationists. The hunting of waterfowl by eagles was also interrupted and may have resulted in lowered success. Bald eagles seldom remained in a perch for long when harassed by snowmobilers, observers, and photographers. Observations of eagles perched far from roads indicated they would remain on the perch longer.

Trumpeter swans appeared to become habituated to moving snowmobiles. However, they fly or swim away upon approach by foot or ski but when a snowmobiler stopped the swans loafed on the bank of the river opposite the trail. The displacement of swans was temporary and the birds moved back to loaf on the trailside bank and fed closer to the trail when traffic ceased. The recreationist disturbance which often flushed the birds from the water undoubtedly created an additional energy expenditure.

Winter Recreation Use

Recent recreation patterns in Yellowstone National Park have radically changed. Winter visitation has increased 955 percent since 1967. The number of private oversnow vehicles entering the park has ranged between 20,000 and 30,000 machines per year since 1972. There are 345 kilometers of snowmobile trails throughout the park. The approximately 72 kilometers of snowmobile trails within the study area received a disproportionate amount of over-snow vehicular travel averaging over 353 machines per day on this trail. In 1978-79, approximately 60.5 percent of snowcoach travel and 75.8 percent of snowmobile travel were concentrated on this small portion of trail from West Yellowstone to Old Faithful Village. Approximately 51 kilometers of this trail meanders through the 5608 hectares of core winter range. The number of recreationists entering the park via snowcoach has increased tremendously. Most of these visitors engage in recreation activities such as skiing and sight seeing. The number of skiers present on trails has risen dramatically and reaches up to 70 persons per day on several major trails. The 80 kilometers of ski trail in the Old Faithful area entertain over 10,000 skiers a year. This averages 117 skiers per day or approximately two skiers per .6 km trail per day. These snowmobile and ski trails within core winter ranges where bison and elk concentrate have increased the degree of contact between winter recreationists and wildlife.

The development of a facilities oriented winter recreation program during the early 70s has played the most significant role in altering winter use patterns in the Park. The trail grooming operation and the operation of Snowlodge have attracted a great number of visitors who would otherwise not have attempted to visit the Park during the winter. The facilities-oriented visitor can now be accommodated during the winter as well as summer months in Yellowstone

National Park. The cost of providing this service per visitor is considerably higher during the winter versus the summer months.

Backcountry use has also increased due to improved access to takeoff points by snowcoach service. More winter campers reach remote regions of the Park than ever before. The numbers of travelers expanding their reach into wilderness areas of the Park during winter months has increased the areas of concern.

Recreationists Effects on the Winter Environment

The results of the lead determination in air samples in this study were not realiable. Lead levels presented in Table 22 are extremely high due to contamination of the samples by lead from sources other than snowmobile exhaust. Clean air of the Rocky Mountain region has been reported as having 200 mg Pb/m^3 while city air has been reported as having 1-70 mg Pb/m^3 (Frederick Dewalt pers. comm.). A close look at the data indicate that lead levels fluctuated with the atmospheric wind conditions and with snowmobile activity in the area. More sampling and better field technique would be required to determine lead concentrations in the air.

Observations of smog generated by snowmobile exhaust tend to confirm that exhaust emissions can temporarily build up in heavily used areas but dissipate overnight or with increasing winds. In the West gate entrance and Old Faithful Village areas a blue haze occasionally developed usually in association with atmospheric conditions such as a temperature inversion or cold calm days.

Lead and organic carbon levels in the snow appeared to be higher on or adjacent to the trail than at a distance of 30 meters or in the control region. Lead precipitate did not drift very far from the trail as indicated by low lead concentrations in the samples taken 30 meters distance from the trail edge. The presence of high levels of lead in vegetation growing near major highways was reported by Warren and Delavault (1960) and Cannon and Bowles (1962). Other authors noted a significant accumulation of lead in soils adjacent to major roads (Williams and Evans 1972).

Lead accumulation in zones of the snow profile was probably associated with wide fluctuations in daily snowmobile traffic. Elgmork, Hagen and Langeland (1973) found grey bands of polluted snow in Norway which were associated with airborne pollutants and contained high levels of lead.

The ecological effects of increased lead in snow have not been thoroughly examined. Adams (1965) found that heavy snowmobile use on frozen lakes can increase lead levels in trout inhabiting these lakes. He found that trout fry exposed to snowmobile exhaust had less stamina as measured by their ability to swim against current than in control fish. In Yellowstone Park lead accumulations in snow adjacent to trails which follow streams and rivers might result in a flush of lead into the water as spring snow arrives although geothermal waters may also contribute significant amounts of heavy metals.

Noise pollution during the winter in Yellowstone Park has become a more serious problem with the development of a winter recreation program. Aside from aesthetic objections, noise pollution may physiologically affect wildlife. Bury (1978) states that development of a stressed condition in response to snowmobile noise has not been proven. However, an Environmental Protection Agency report on the effect of noise on wildlife suggests that noise may act as a physiological stress-or producing changes similar to those brought about by exposure to extreme heat, cold, pain, etc. (EPA 1971). The report states that, "clearly, the animals that will be directly affected by noise are those capable of responding to sound energy and especially the animals that rely on auditory signals to find mates, stake out territories, recognize young, detect and locate prey and evade predators. Further, these functions could be critically affected even if the animals appear to be completely adapted to the noise (i.e. they show no behavioral response such as startle or avoidance)." The application of noise control standards to snowmobiles has reduced this problem since the EPA report.

Physical damage to soil and plants by snowmobiles has been reported by several authors (Wanek 1971, 1973, Neuman and Merriam 1972 and Whittaker 1971). Bayfield (1970) reported damage to vegetation from use by tracked vehicles and from walking and skiing. In Yellowstone Park little damage to plants and soil by snowmobiles occurred. Restriction of snowmobiles to groomed trails and the location of the trail above an existing roadway have reduced the potential for damage to soil and plants.

It seems clear that intensity of recreation activity, distribution of use, timing of recreation activity and the sensitivity or tolerance of wildlife species are four important considerations when designing a functional recreation-management plan that is concerned with recreation activities and minimizing impacts on the wildlife and the ecosystem in general.

MANAGEMENT RECOMMENDATIONS

The major snowmobile route from West Yellowstone to Old Faithful Village currently transects the heart of important wintering habitat for wildlife within the region. The location of the trail through core winter ranges and along the water-courses important to wintering wildlife poses the most serious problems to wildlife. Re-routing the snowmobile traffic via a trail which skirts the core ranges but perhaps allows visibility of wildlife at a distance, would be a beneficial step in minimizing wildlife-recreation activity conflicts. Between the trail and core range one should provide a safe buffer zone which would allow sensitive species such as large carnivores and predators that are dependent on the wintering ungulates, to move about more freely. The trail should be placed so that it does not intersect major migration routes of bison.

An alternative to the above plan might be to encourage traffic to Old Faithful via Southgate entrance. Travel on the West Yellowstone to Old Faithful route may be maintained but restricted to well planned, guided tours led by a qualified naturalist. This would increase the interpretive contact with snowmobilers, which are the least frequently reached group under the current operation. At the same time it would ensure that illegal off road use would be eliminated and would be most beneficial to the education and safety of the Park visitor.

In general over-snow vehicular activity between the hours of 10:00 a.m. and 3:00 p.m. has the least impact on wintering wildlife. If guided tours are conducted it should be during the mid-day period. Snowcoach schedules should preclude the early morning, early evening period and perhaps the coaches should be operated in convoys.

Continual monitoring of snowmobile activity in the Park is recommended. The photo electric eye system should be expanded and semi-permanent installations with automatic recorder attached could add detailed information to the current data.

It was not possible to recommend trail changes for the skiing operation. Currently, trailheads are located in core ranges but radiate from them into peripheral winter ranges or beyond. Most ski activity centers around the Old Faithful area and should remain centered there. Encouraging use of trails and educating the public towards the implications of wildlife encounters with recreationists should be increased if possible. Off trail use is the most serious problem associated with skiing. The back-country-use permit system has proven very useful and should be continued throughout the winter period. Restrictions in the Nez Perce drainage are important and should be maintained. Increasing skier use in the geyser basins should be monitored more closely perhaps with strategically placed photo-electric eye systems and automatic recorders. Snowshoe activity also has a similar potential to impact wildlife. It is currently insignificant but should be monitered.

If a significant increase in winter recreation use in the West Yellowstone-Old Faithful area occurs, a restrictive limit on the numbers of recreationists allowed into this area may be necessary. This might reduce interest in the West Yellowstone-Old Faithful snowmobile route and increase interest in some of the remaining 272 km. of snowmobile trail within the Park. Proper distribution of current demand-use levels would benefit the wildlife as well as the recreationist.

As mentioned previously, the March-April period is a time of year critical to most species of wildlife within the park. Recreation activity during such time probably has its greatest impact. Due to the critical nature of this time and in best interest of wildlife it would not be recommended to extend the winter recreation activity within core winter ranges beyond the second week of March.

Levels of lead in the air or snow indicated low pollution levels in the park as a result of winter recreation activities. Increased lead levels in the air were usually temporary in nature and occurred within certain atmospheric conditions coupled with intense snowmobile-snowcoach operation in the Old Faithful Village and West Entrance Station. Lead levels adjacent to and on the road were higher than at 30 meters from the roadside and in the control area. No recommendation regarding air and snow pollution can be made at this time. An in-depth study of this aspect of winter recreation impacts may be necessary.

Litter was a minor problem but nonetheless did occur. A campaign to prevent littering during winter operations is recommended. Ironically the greatest source of litter was maps and pamphlets handed out to snowmobile operators at entrance gates.

Plowing of the roads into Old Faithful Village has been suggested in recent years. Based on data from this study plowed roads would increase wildlife-recreationist interaction and provide a much greater barrier for free ranging wildlife. Recreationists in cars were least likely to give right of way to wildlife.

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APPENDIX

Table 26. Elk classifications made during 1978-79 and 1979-80 in the upper Madison, Firehole, and Gibbon River Valleys, Yellowstone National Park.

					per 100 cows		
Year	Number	Calves	Yearling Males	Adult Bulls	Calves	Yearling Males	Adult Males
1978-79							
December	175	55	7	4	50	6	4
January	--	--	--	--	--	--	--
February	306	80	14	11	40	7	6
March	86	18	5	3	21	8	5
April	111	16	5	5	19	6	6
1979-80							
December	--	--	--	--	--	--	--
January	220	59	5	4	39	3	3
February	171	39	4	9	23	2	5
March	252	46	4	23	18	2	9
April	228	30	3	9	16	2	5

Table 27. The number and percent of adult bull elk observed during an aerial survey made on February 28, 1980 in Yellowstone National Park.

	Number elk observed	Adult Bulls observed	Percent bulls
Lower Madison and Duck Creek-Cougar Creek	339	89	26
Upper Madison	119	8	7
Gibbon	106	9	9
Firehole	373	25	7

Table 28. The number and percentage of private oversnow vehicles entering through each entrance gate, 1976-1980 in Yellowstone National Park.

	1976-77 number-percent		1977-78 number-percent		1978-79 number-percent		1979-80 number-percent	
North	481	2.3	885	3.3	1,192	4.8	604	2.2
West	15,800	77.2	20,912	78.7	18,905	75.8	19,501	70.5
South	3,229	15.8	3,411	12.8	3,371	13.5	5,667	20.5
East	966	4.7	1,349	5.2	1,459	5.9	1,899	6.8

Table 29. The number and percentage of snowcoaches entering through each entrance gate, 1976-1980 in Yellowstone National Park.

	1976-77 number-percent		1977-78 number-percent		1978-79 number-percent		1979-80 number-percent	
North	--	--	--	--	--	--	--	--
West	365	60.9	644	69.2	658	60.5	1,038	55.6
South	234	39.1	286	30.8	429	39.5	829	44.4
East	--	--	--	--	--	--	--	--

Table 30. Number of camp-nites spent at each area during the 1979-80 winter season by backcountry users in Yellowstone National Park.

Area	Camp nites
Shoshone Lake	99
Old Faithful	85
Lonestar Geyser and Upper Firehole	69
Bechler and Falls River	40
Imperial Geyser	21
Sentinel Creek	8
Mary Mountain-Nez Perce Creek	8
Heart Lake	7
Lewis Lake	7
Mallard Lake	4
Seven Mile Bridge	4
Summit Lake	4
Madison Junction	4
Grants Pass	2
Little Firehole Meadows	1
Nez Perce Picnic grounds	1
Other regions	29

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