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

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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Approved:

Chairman, Graduate Committee

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Bozeman, Montana

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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).

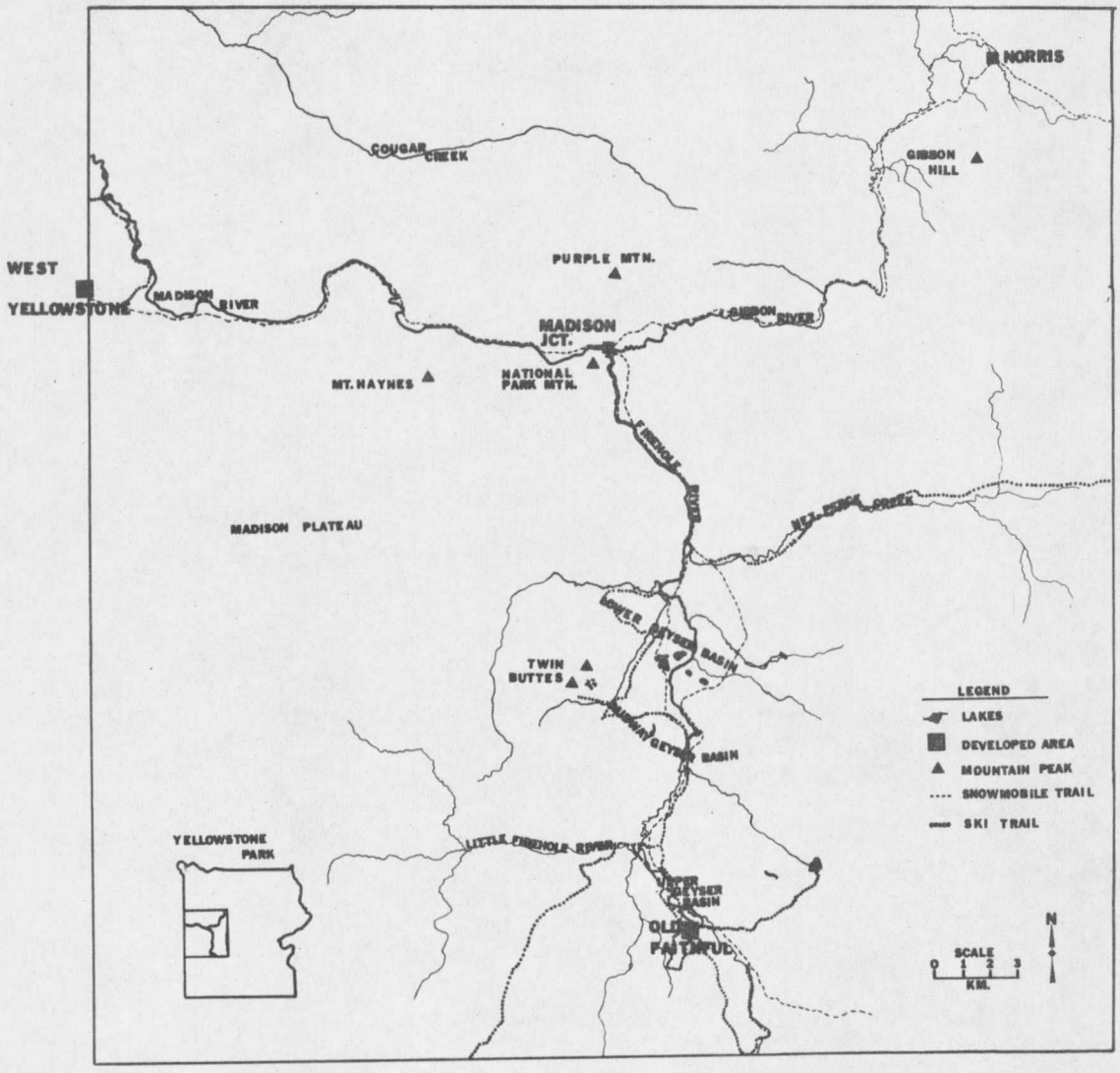

Figure 1. Map of the Study Area

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

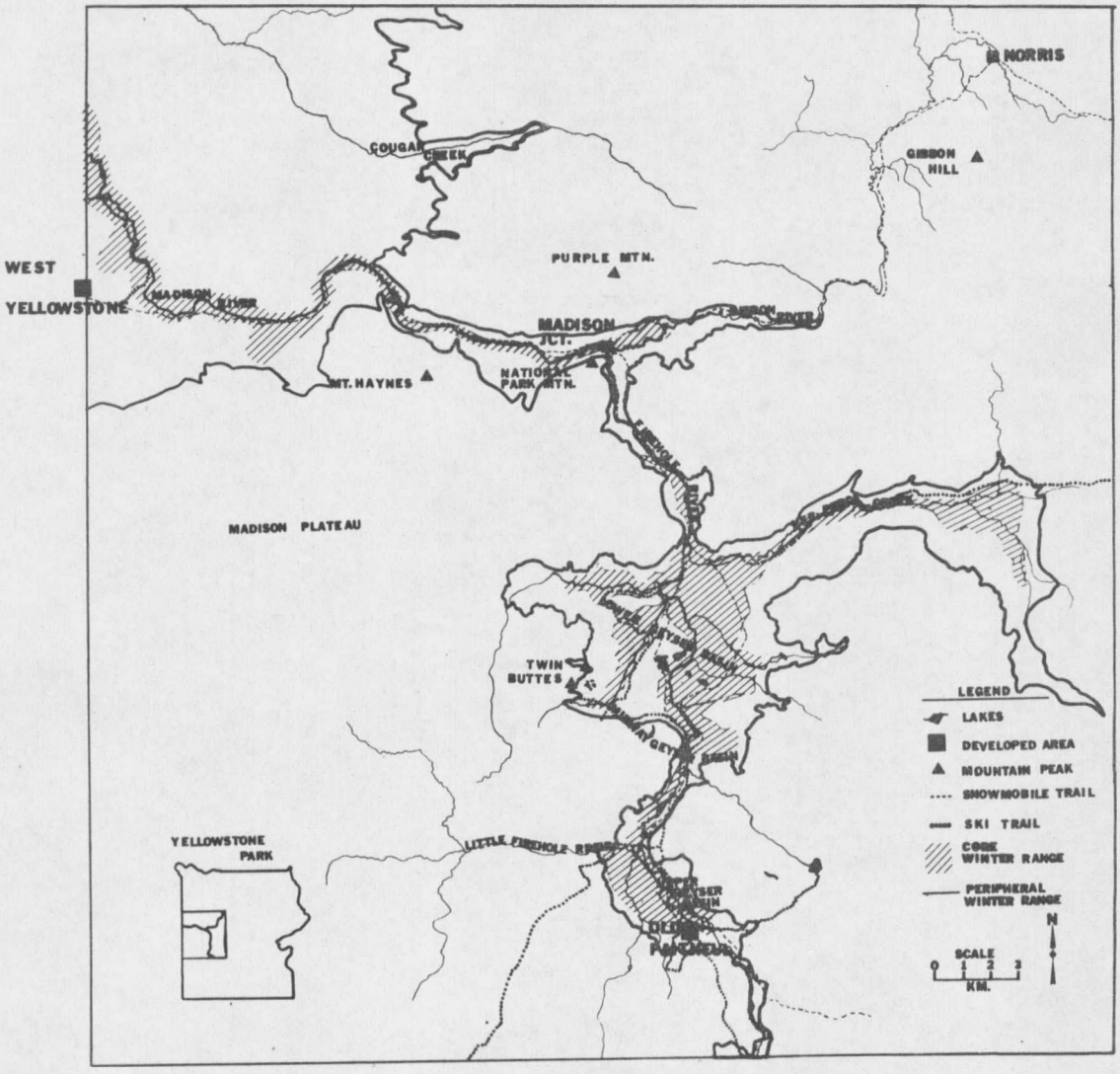

Figure 2. Core and peripheral winter ranges of elk and bison, 1978-80.

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/]

	HELICOPTER		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.

Year	October - December				March - Early April			
	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 Number	1978-79 % Calves	1978-79 % Bulls	1979-80 Number	1979-80 % Calves	1979-80 % 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.

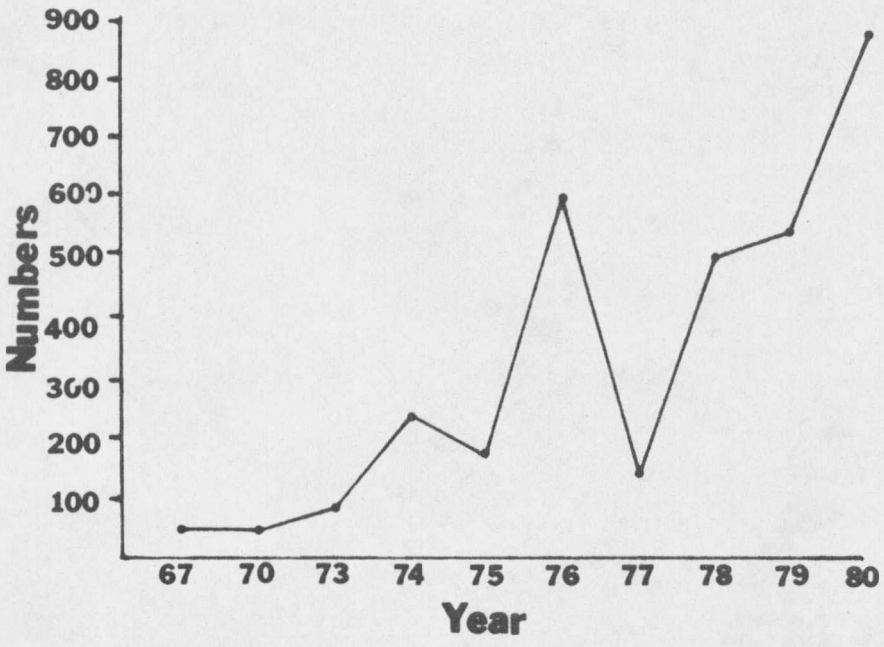

Fig. 3. The number of bison aerially censused in the Firehole River Valley 1967-1980. (M. Meagher, personal communication.) The 1977 count does not represent a population low, only that the bison were in Hayden Valley.

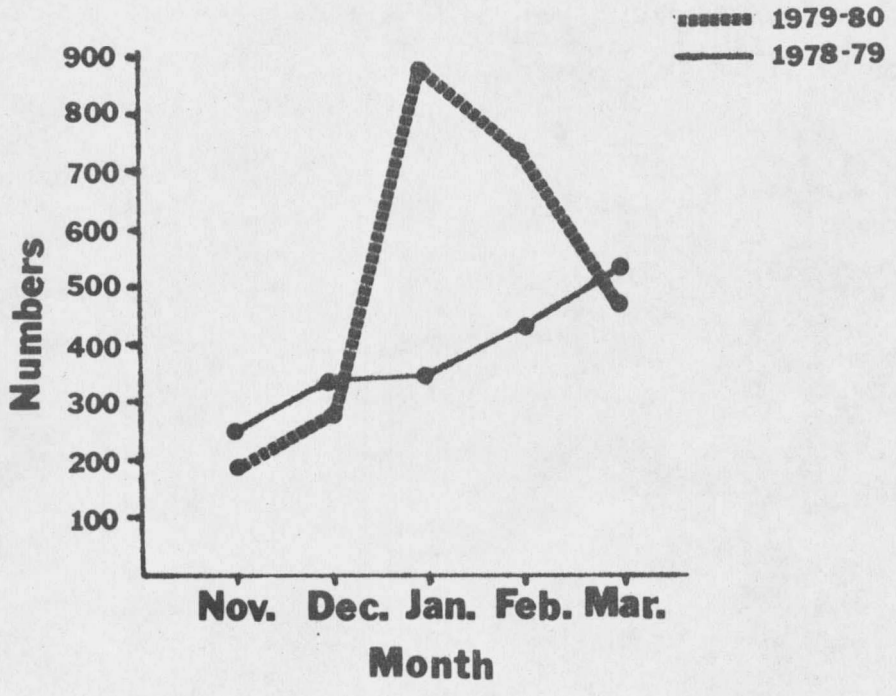

Fig. 4. The number of bison aerially censused each month in the Firehole River Valley 1978-1980. Changes reflect interchange with Hayden Valley.

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 spacial 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

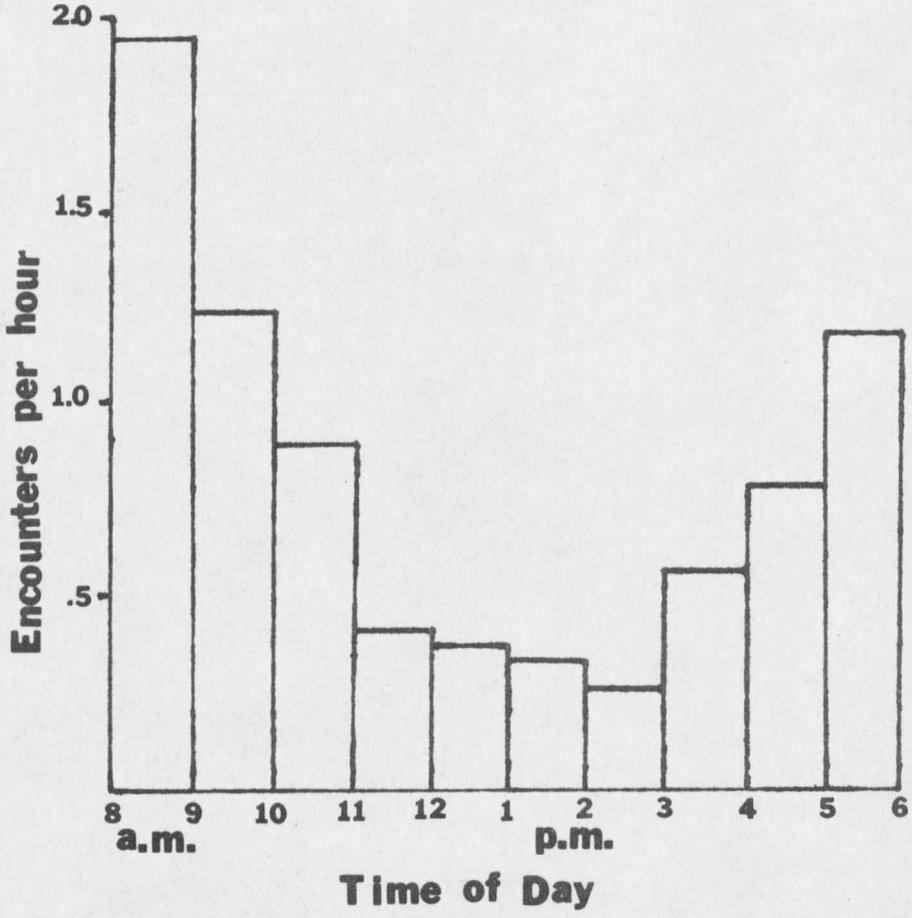

Figure 5. The daily time period distribution of snowmobile-wildlife interactions for all species during the snowmobiling seasons, 1978-80.

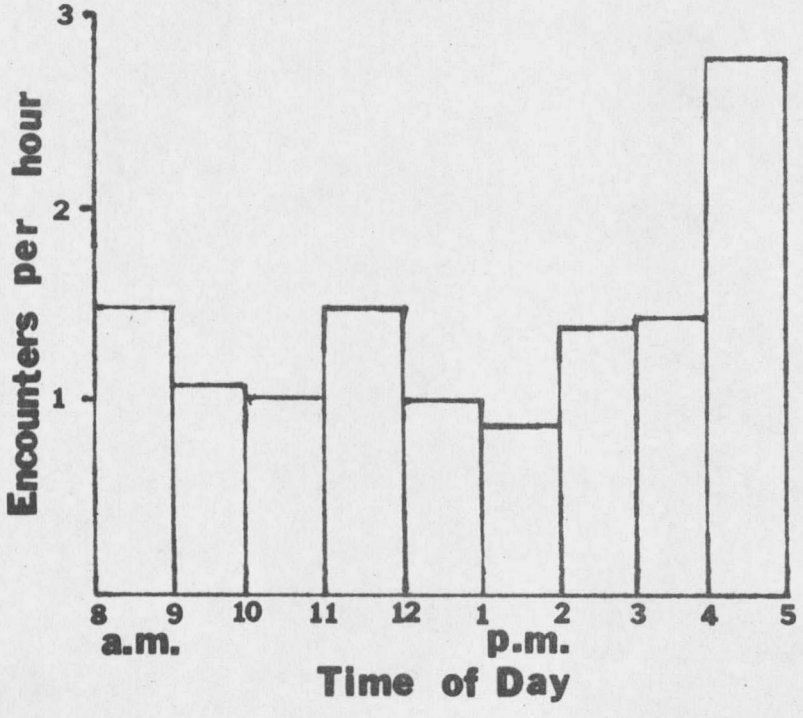

Figure 6. The daily time period distributions of snowmobile-wildlife interactions for all species during the preseason, 1978-79.

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.

Interaction by Individual Species

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		December 16 -January 31		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

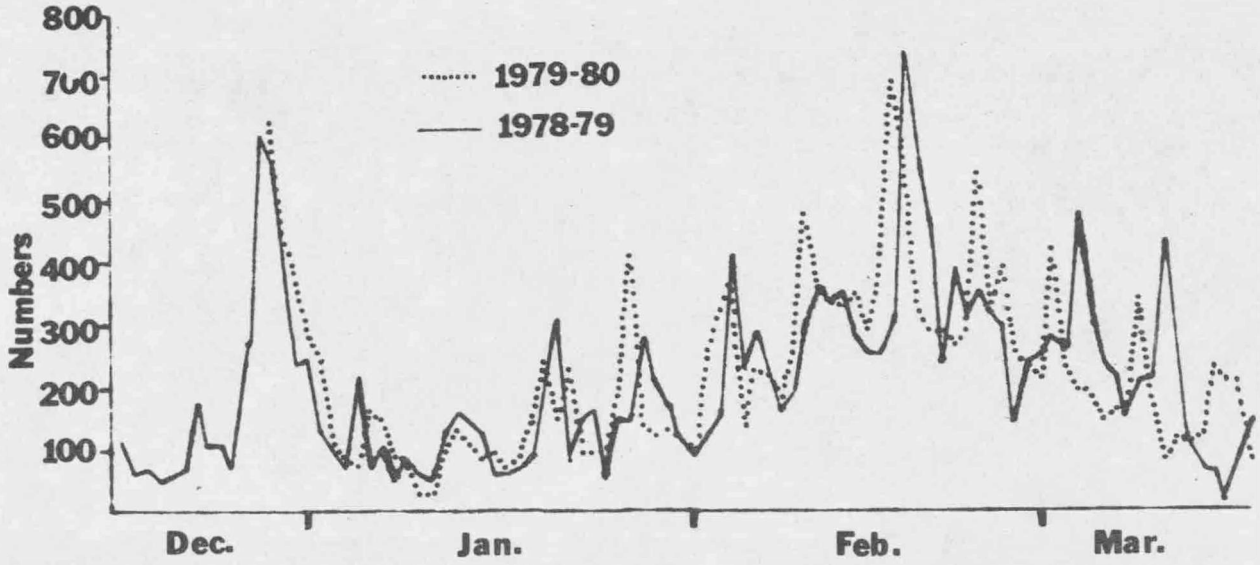

Figure 7. Daily numbers of snowmachines entering through the West gate entrance to Yellowstone National Park. 1978-80.

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