Factors Influencing The Frequency of Road-killed Wildlife in Yellowstone National Park

Kerry A. Gunther, Mark J. Biel, and Hillary L. Robison
Bear Management Office
Yellowstone National Park, WY

Abstract

During the 8 year (1989 - 1996) study period, 939 large mammals were killed by vehicles on roads within Yellowstone National Park (YNP). Elk and mule deer were the species most often killed by vehicles on park roads. Other species killed on park roads include bison, moose, coyote, antelope, beaver, whitetail deer, bighorn sheep, black bear, bobcat, grizzly bear, raccoon, and wolf. Vehicle-wildlife collisions pose a safety threat to people as well as wildlife. Park visitors have been injured and killed in vehicle collisions with wildlife. We analyzed the frequency of road-kills in relation to adjacent roadside cover types, posted speed limits, and actual average speed of vehicles. We also estimated the proportion of the park's large mammal populations killed by vehicles each year. We concluded that speed of vehicles was the primary factor contributing to vehicle-wildlife collisions. Road design appeared to influence vehicle speed more than the posted speed limit. Cover types and wildlife population numbers also influenced the frequency of vehicle wildlife collisions. Most wildlife species were killed significantly more often in non-forested cover types than in forested types. Wildlife species with the highest population numbers were also the species most often killed by vehicles. Overall, vehicle-caused wildlife mortality does not appear to have a significant negative impact on large mammal populations in the park. However, road-killed wildlife carcasses appear to be a significant source of nutrition for some individual carnivores and scavengers whose home ranges encompass wildlife carcass disposal sites.

Introduction

Prior to 1877, only packtrains could manage YNP's "roads." These early roads resembled trails and often had stumps sticking anywhere from 2 - 20 inches above the ground (Culpin 1994). In 1872, Nathanial P. Langford, the first superintendent of YNP, expressed the need to open up the wonders of Yellowstone to visitors by creating carriage roads through the park. Langford's plans eventually resulted in a road system that was almost a mirror image of the present-day road configuration (Culpin 1994). The first roads which entered YNP were privately built and entered the park at the north and west entrances. Superintendent Langford appealed for an appropriation to construct roads, make improvements, and protect park resources twice in 1873 and once in 1874 without any success.

In 1878, under the leadership of the second superintendent, Philetus Norris, the park received its first appropriation of $10,000 for road improvements. Norris, like Langford, expressed the pressing need for a road connecting most of the scenic wonders of YNP. Norris suggested building a "loop road" starting from Mammoth Hot Springs, via Tower Falls, Mount Washburn, Cascade Creek, Yellowstone Falls, the Lake, the Firehole Basin, and ending at Henry's Lake outside the park's West Entrance (Culpin 1994). By the end of 1878, there were close to 104 mi of roads, more often resembling trails, in YNP (Culpin 1994). These 104 mi of road accounted for approximately two thirds of the current 140 mi of the Grand Loop Road.

In 1883, spurred by the destruction of park geothermal features and wildlife, administration of YNP was turned over to the military. By 1887, with new road segments built by the Army Corp of Engineers, there were 184 mi of wagon roads (Culpin 1994). By 1906, the Grand Loop Road resembled its present 251 mi configuration with roads heading to the North, Northeast, East, South, and West entrances. In 1912, Congress appropriated money for improving YNP's roads for automobiles. Until 1915, roads were accessible only by horse and horse drawn wagons and carriages.

From the beginning of the road building program, road routes were chosen for directness and often crossed streams, wetlands, meadows, and thermal areas. Ecological impacts on terrain, habitat, and wildlife were given little consideration (Bartlett 1985). Major considerations for road planning were limited to the ease and economy of construction, scenic interest, visitor convenience, and minimum disturbance to the landscape (Craighead et al. 1995). Therefore, many of these original roads were built along river and stream bottoms, thereby disturbing riparian areas. Both the physical presence of and associated human activity along roads alter animal use patterns. Most of YNP's present road system follows these old wagon and early automobile routes. Because of the lack of ecological foresight in building these roads with respect to animal use patterns, travel corridors, and preferred habitat, vehicle-animal collisions are common.

YNP keeps records of the number of large mammals (species in which adults weigh 30 lbs or more) killed in vehicle-animal collisions on roads within the park. The primary objectives for keeping records of wildlife carcasses are to: 1.) facilitate the proper disposal of large mammal carcasses so as to reduce the potential for bear-human conflicts at road-killed carcasses, and 2.) reduce the potential road hazard to scavengers that may be attracted to large mammal carcasses. In addition, the road-killed carcass data collected may also be useful for other resource management purposes such as evaluating highway reconstruction alternatives, highway speed limits, enforcement of speed limits, road design, roadside visibility, and the placement of roadside wildlife hazard signs.

We analyzed the frequency of road-killed wildlife in relation to adjacent roadside cover types, posted speed limits, and actual average speed of vehicles. We also estimated the proportion of the park's large mammal populations killed by vehicles each year to evaluate the impacts of road-kill mortality on the park's wildlife populations.

Study Area

YNP encompasses approximately 898,383 ha (2,219,823 acres) in the states of Wyoming, Montana, and Idaho. The park, established March 1, 1872, was "dedicated and set apart as a public pleasuring-ground for the benefit and enjoyment of the people" and "for the preservation, from injury or spoilation, of all timber, mineral deposits, natural curiosities, or wonders... and their retention in their

natural condition."

YNP is currently inhabited by 18 different species of large mammals that can attain weights of 30 lbs or more as adults. These species include: 1.) antelope (*Antilocapra americana*); 2.) beaver (*Castor canadensis*); 3.) bighorn sheep (*Ovis canadensis*); 4.) bison (*Bison bison*); 5.) black bear (*Ursus americanus*); 6.) bobcat (*Felis rufus*); 7.) coyote (*Canis latrans*); 8.) elk (*Cervus elaphus*); 9.) grizzly bear (*Ursus arctos horribilis*); 10.) lynx (*Felis lynx*) 11.) moose (*Alces alces*); 12.) mountain goat (*Oreamnos americanus*); 13.) mountain lion (*Felis concolor*); 14.) mule deer (*Odocoileus hemionus*); 15.) raccoon (*Procyon lotor*); 16.) whitetail deer (*Odocoileus virginianus*); 17.) wolf (*Canis lupus*); and 18.) wolverine (*Gulo gulo*).

During the 8-year study period (1989 - 1996), 23,777,812 people visited YNP, an average of 2,972,227 visitors per year. Most (>80%) visitation occurred during the 4 month period from June through September. The park currently has approximately 268 miles of paved roads with 6 different posted speed limits. Speed zones include 1.1 miles of road posted at 15 mph, 18.6 mi posted at 25 mph, 24.9 mi posted at 35 mph, 24.5 mi posted at 40 mph, 178.3 mi posted at 45 mph, and 20.2 mi posted at 55 mph. Primary roads in YNP occur in 20 different cover types (c.t.) (Mattson and Despain 1985):

1) Climax and post-disturbance lodgepole pine (LP1/LP) c.t. complex. The LP1/LP is an area with an intermixed mosaic pattern of the LP1 (#17) and LP (#5) c.t.'s described below.

2) Post-disturbance whitebark pine (WB0) c.t. Recently burned whitebark pine stands usually near upper timberline where whitebark pine clearly dominates reproduction.

3) Post-disturbance douglas-fir (DF0) c.t. Burned douglas-fir stands in the grass to seedling/sapling stage before canopy closure. Reproduction mostly douglas-fir.

4) Post-disturbance lodgepole pine (LP0) c.t. Recently burned lodgepole pine stands in the grass to seedling/sapling stage before canopy closure. Approximately 0-40 years post fire.

5) Climax lodgepole pine (LP) c.t. Canopy dominated by overmature lodgepole pine beginning to break up. Understory of lodgepole pine and whitebark pine. Stands usually on rhyolite and multi-aged. Lodgepole is climax or persistent seral species. Three hundred plus years post fire.

6) Non-forest (NF) c.t. Non-forested components include shrublands, meadows, grasslands, and naturally occurring forest openings. Exposed bedrock, talus, open water, and stream-courses are also included. All of these sites do not potentially support a closed forest canopy or a woodland of regularly spaced trees. Recently burned sites which will support forest stands are therefore not considered to be non-forested components.

7) Late successional lodgepole pine (LP3) c.t. Canopy quite ragged, predominately of overmature lodgepole pine but containing some engleman spruce, subalpine fir, and whitebark pine in the pole-sized class. Old growth lodgepole pine successional stage. Understory of small to large spruce and fir seedlings and saplings. Three hundred plus years post fire.

8) Climax engleman spruce and subalpine fir and non-forest (SF/NF) c.t. complex. The SF/NF is an area with an intermixed mosaic pattern of the SF (#9) c.t. described below and the NF (#6) c.t. described above.

9) Climax engleman spruce and subalpine fir (SF) c.t. Stands dominated by engleman spruce and subalpine fir in both overstory and understory. Lodgepole pine, douglas-fir, or whitebark pine may be present, but are a minor stand component.

10) Climax whitebark pine (WB) c.t. Stands of mature to overmature whitebark pine where the reproduction is nearly all whitebark pine.

11) Climax whitebark pine and non-forest (WB/NF) c.t. complex. The WB/NF is an area with an intermixed mosaic pattern of the WB (#10) and NF (#6) c.t.'s described above.

12) Climax douglas-fir and non-forest (DF/NF) c.t. complex. The DF/NF is an area with an intermixed mosaic pattern of the DF (#13) c.t. described below and the NF (#6) c.t. described above.

13) Climax douglas-fir (DF) c.t. Climax to near climax stands dominated by mature to overmature douglas-fir, often in scattered islands in a non-forest matrix.

14) Late successional lodgepole pine and non-forest (LP3/NF) c.t. complex. The LP3/NF is an area with an intermixed mosaic pattern of the LP3 (#7) c.t. and the NF (#6) c.t. described above.

15) Middle and late successional lodgepole pine (LP2/LP3) c.t. complex. The LP2/LP3 is an area with an intermixed mosaic pattern of the LP2 (#20) c.t. described below and the LP3 (#7) c.t described above.

16) Aspen (ASP) c.t. Mature to overmature stand where aspen is climax or a long persistent seral species; sapling or pole-sized aspen are usually well represented and indicates the persistence of aspen dominance through at least another stand cycle. Conifer species representation is limited to a few individuals, typically of sapling to mature classes.

17) Early successional lodgepole pine (LP1) c.t. Closed canopy of even-aged, usually dense, lodgepole pine where trees are younger and shorter than those of neighboring stands. Young pole successional stage. Approximately 40-100 years post fire.

18) Middle successional lodgepole pine and non-forest (LP2/NF) c.t. complex. The LP2/NF is an area with an intermixed mosaic pattern of the LP2 (#20) c.t. and the NF (#6) c.t described above.

19) Middle and climax lodgepole pine (LP/LP2) c.t. complex. The LP/LP2 is an area with an intermixed mosaic pattern of the LP (#5) c.t. described above and the LP2 (#20) c.t. described below.

20) Middle successional lodgepole pine (LP2) c.t. Closed canopy dominated by lodgepole pine. Overstory still largely intact. Mature lodgepole pine successional stage. Understory usually small to medium engleman spruce and subalpine fir seedlings and saplings but also may be mostly lodgepole pine. Approximately 100-300 years post fire.

Detailed descriptions of the geology (Keefer 1972, U.S. Geological Survey 1972), climate (Dirks and Martner 1978), vegetative characteristics (Despain 1990), and fauna (Streubel 1989, U.S. Fish and Wildlife Service 1994) of YNP have been previously reported.

Methods

Road-killed wildlife data was collected from park ranger case incident reports and from reports turned in by other park employees and visitors from 1989-1996. This data was entered into a computer database which allows sorting of the data by species, sex, age class, date of death, and location coordinates for each animal killed. An unknown number of animals are hit by vehicles and survive long enough to move out of sight of the road corridor before dying and are not found or reported.

Vehicle odometer readings were used to determine the distance of road-killed animals from known landmarks such as road intersections, trailheads, or geographic features. Locations were then plotted on USGS 7.5 minute topographic maps and Universal Transverse Mercator (UTM) grid coordinates calculated for each road-kill. Vegetation in YNP has been classified, mapped, and digitized to a 2-ha resolution (Despain 1990). Posted speed zones were field mapped using a global positioning system and digitized. Locations of road-killed wildlife were then plotted on maps containing cover types and posted road speeds to determine the cover types and speed limits where animals were struck and killed by vehicles.

YNP contains 15 primary paved road segments, each of which extends from one major intersection to the next. Average actual vehicle speeds were collected on all 15 major road segments by two different methods between July 8, 1997 and October 12, 1997. The first method consisted of park law enforcement rangers measuring

vehicle speeds with radar units (n=964). The second method (timed/distance method) consisted of Bear Management Office personnel calculating road speeds by timing vehicles over a known distance (n=448). Speeds were collected from 1,412 vehicles traveling on the 15 major road segments over the 96 day period. Areas where speeds were documented by the radar method were selected based on 1) locations where law enforcement personnel felt those speeds were representative of speeds along the overall road segment, and 2) areas where the patrol car was concealed, if possible. Speeds calculated by the timing method were picked for visibility and were usually straightaways. Speeds were collected in the morning (0400-1200 hrs), afternoon (1201-1800 hrs), and night (1801-0359 hrs) when possible. The types of vehicles sampled included sedans, trucks, semis, trucks pulling trailers, recreational vehicles, motorcycles, and sport/utility vehicles.

Population estimates for large mammals in the park were obtained from published literature when available. When published population estimates were not available, estimates were obtained from experienced species specialists. For some species which have not been studied population estimates were not available.

For statistical analysis, Goodness of Fit and Chi Square tests followed procedures described by Zar (1974). Occurrence versus availability tests followed techniques described by Neu et al. (1974).

Results

From 1989 - 1996, a total of 939 large mammals were reported hit and killed by vehicles within the park, an average of 117.4 (± 16.5 SD) per year (Table 1). Elk (40%, n=375), and mule deer (30%, n=286) were the species most often killed in collisions with vehicles. Other species killed by vehicles include bison (8%, n=79), moose (8%, n=76), coyote (7%, n=66), antelope (2%, n=19), whitetail deer (1%, n=9), beaver (1%, n=11), bighorn sheep (<1%, n=5), black bear (<1%, n=5), bobcat (<1%, n=2), grizzly bear (<1%, n=2), raccoon (<1%, n=1), and wolf (<1%, n=3). The number of road-kills per year ranged from a low of 97 in 1989, to a high of 148 in 1994 (Table 1).

Influence of Posted Speed Limits

Most (85%) road-kills occurred in areas where the posted speed limit was 45 mph (44%, n=418) and 55 mph (41%, n=382) (Table 2). Based on the proportion of park roads posted at different speeds, the frequency of road-kills was not independent of speed limits (X^2=18.467, p<0.001) (Table 3). Large mammals were killed by vehicles significantly more than expected on roads with posted speeds of 55 mph (p<.10) and significantly less than expected on roads with posted speeds of 45 mph or less (p<.10) (Table 3).

Average Actual Speeds

As determined by radar, average actual speeds were within 1 mph of the posted speed limits in the 35 (range 26 - 48 mph) and 45 mph (range 24 - 70 mph) speed zones. However, in the 55 mph speed zones, average actual speeds exceeded the posted speed limit by 16 mph (range 40 - 84 mph) during the study. Although not recorded during our study, speeds as high as 112 mph have been recorded in the 55 mph speed zones in the past.

As determined by the timed/distance method, average actual speeds were within 3 mph of the posted speed limits in the 35 (range 27 - 38 mph) and 45 mph (range 17 - 77 mph) speed zones. In the 55 mph speed zones, actual speeds averaged 64 mph (range 49 - 88 mph) during the study period.

Influence of Road Reconstruction

An ongoing road reconstruction project on the East Entrance road allowed a comparison between vehicle speeds on a section of old road and a section of newly reconstructed road with the same posted speed. The segment of old road (east of Sylvan Pass) was characterized by narrow pavement widths (22-24 ft), abrupt edges, and no shoulders, with numerous potholes, cracks and frost boils. The segment of newly reconstructed road (west of Sylvan Pass) was characterized by a wider paved width (30 ft), the presence of road shoulders, and a smooth, uncracked surface lacking potholes. Although the posted speeds of the two road segments were identical, on average vehicles traveled 5 mph faster on the newly reconstructed road segment.

Recent road work on the West Entrance and Norris to Canyon Roads allows comparison of the number of road-kills before and after road reconstruction. In 1992 a large portion of the West Entrance Road was under construction as part of a 3-R (resurfacing, restoration, and rehabilitation) overlay project. During the 3 year period (1989-1991) prior to the overlay project, an average of 7 (± 4 SD) large mammals per year were killed by vehicles on the West Entrance road (Table 4). During the 4 year period (1993-1996) after the majority of the overlay project was complete, the number of road-kills on the West Entrance road increased significantly (X^2=5.6648, p<0.05) to an average of 13 (± 5 SD) per year (Table 4).

In 1993, the majority of a 3-R overlay project on the Norris to Canyon road segment was completed. Prior to the project (1989-1992), an average of 6 (± 3 SD) large mammals were hit and killed by vehicles each year on this road segment (Table 4). After the overlay was completed (1994-1996), an average of 8 (± 3 SD) large mammals were hit and killed by vehicles on the road, a slight, but not statistically significant (X^2=1.4158, p>0.10) increase from the 1989 - 1992 period (Table 4).

Influence of Cover Type

Overall, the amount of road-killed wildlife was not independent of cover-type (G=182.1, df=10, p<.001) (Table 5). Based on the proportion of forest (68%) and nonforest (32%) cover types present along park road corridors, antelope, bison, coyote, and elk were all killed by vehicles significantly more than expected in nonforested cover types (p<.001) (Table 5). Mule deer were killed by vehicles significantly less than expected in nonforest and more than expected in forested cover types (p<.001) (Table 5). Moose were killed in proportion to forest and nonforest cover types available (Table 5). The number of beaver, bobcat, bighorn sheep, black bear, grizzly bear, raccoon, whitetail deer, and wolf killed by vehicles were too small to conduct valid statistical analysis.

Of the 488 large mammals that were killed by vehicles in forested cover types, most (84%) were killed in the LP0 (34%), LP1 (8%), LP2 (27%), and LP3 (15%) cover types (Table 6). These cover types comprise approximately 51% of the forested habitat along roadside corridors in the park.

Influence of Population Size

The frequency that species of large mammals were hit and killed by vehicles was not independent of the population size of the species (r=0.793, p=.011). As expected, species with the largest populations such as elk were killed significantly more frequently than species with smaller population sizes such as the wolf (Table 7).

Impacts of Road-kill on Wildlife Populations

Two percent of the estimated park population of wolves and mule deer were killed by vehicles each year (Table 7). These were the highest proportions of the total populations of any species killed by vehicles on park roads. For all other species of large mammals, 1% or less of the estimated park populations were killed in collisions with vehicles each year (Table 7). The percentage of the estimated population killed by vehicles per year could not be determined for bobcat, raccoon, and whitetail deer, species for which population studies and estimates have not be made.

Discussion

Vehicle speed appears to be the most significant factor

influencing the frequency of vehicle-wildlife collisions in YNP. Vehicle speed appears to be influenced by several factors including road design, road condition, posted speed limit, and visitor compliance with speed limits. Wildlife cover type preference and population abundance also appear to have some influence on the frequency of vehicle-wildlife collisions.

Influence of Vehicle Speeds on Frequency of Road-kill

Road-kills occurred much more frequently on straighter, wider roads where vehicles traveled faster, regardless of posted speed limits. U.S. Highway #191 makes up approximately 7% of the paved roads within YNP but accounted for 41% of the reported road-kills within the park. U.S. Highway #191 has wider lanes than other park roads and wide, paved shoulders. It is also the only park road with a 55 mph speed limit and actual average speeds are much greater. All other roads within the park are posted at 45 mph or slower.

The increase in the number of road-killed large mammals on both the West Entrance and Norris to Canyon road segments following reconstruction and resurfacing, suggests that faster vehicle speeds on newer road surfaces may be partially responsible for the observed increase in road-killed wildlife on these two roads. Following completion of the West Entrance road resurfacing project in 1993, the number of speeding tickets issued on that road segment increased by 60% and the average speed of vehicles caught speeding increased 25% (Caslick 1994). The number of road-killed on the West Entrance road also increased significantly following the reconstruction project.

Factors Influencing Vehicle Speeds

Road design, road condition, and posted speed limit all appeared to have some influence over actual vehicle speeds. On average, actual vehicle speeds were significantly higher than posted speed limits on straight, wide roads. Vehicles speeds tended to be relatively close to posted speed limits, or even below posted speed limits, on narrow, winding roads. Vehicle speeds also tended to be slower on roads where pavement was in poor condition with numerous cracks, potholes, and frost boils than on newly resurfaced roads in good condition. Posted speed limits apparently had the least amount of influence over vehicle speeds. Average actual vehicle speeds were very close to posted speed limits on road segments where design (straightness and width) and condition (smoothness) appeared to reduce vehicle speeds. Actual speeds averaged 16 mph higher than the posted speed limits on road segments where design and condition did not act to slow vehicle speeds.

Influence of Cover Types

Cover type appeared to influence the frequency of vehicle-wildlife collisions. Based on the availability of nonforested habitat along park road corridors, antelope, bison, coyote, and elk were hit and killed by vehicles significantly more often than expected in nonforested areas. The major foods of these species are found predominately in nonforested areas and may have been concentrating these animals in nonforested areas.

Influence of Wildlife Distribution and Population Size

The frequency of vehicle-wildlife collisions on different road segments was influenced by the geographic distribution of different wildlife species within the park. Wildlife were killed more frequently in areas where they were common than in areas or habitat they rarely frequented. For example, antelope and bighorn sheep were most frequently killed on the north side of the park and whitetail deer on the west side of the park. These areas coincide with the primary geographic ranges of these species within the park.

The size of different wildlife populations also influenced the frequency of vehicle-wildlife collisions. Species with the highest population numbers such as elk, bison, and mule deer were killed by vehicles significantly more often than species with low population numbers such as wolves, bobcats, and raccoons.

Impacts of Road-kill on Wildlife Populations

Overall, vehicle-wildlife collisions appear to be an insignificant cause of mortality for all species of large mammals in the park. For most species, 1% or less of the estimated populations were killed by vehicles each year. For wolves and mule deer, 2% of the estimated park populations were killed annually in collisions with vehicles. Wolves were only present in YNP for the last 2 years of the 8 year study period and were at low population numbers. Due to the high reproductive potential of wolves, we expect that human tolerance and prey availability will become much more significant factors in regulating wolf population numbers than collisions with vehicles once wolves have become more established in the park.

Potential Benefits of Road-kill to Carnivores

Grizzly bears, black bears, coyotes, ravens, magpies, and bald eagles are known to consume road-killed ungulate carcasses. These species are known to seek out and consume road-killed wildlife carcasses in YNP. Up to four different grizzly bears have been observed feeding on the carcass of a single road-killed bison during one day. Ungulate meat is one of the highest sources of digestible energy for bears in the Yellowstone ecosystem (Craighead et al. 1995). Road-killed wildlife carcasses appears to be a significant source of nutrition for carnivores and scavengers whose home ranges encompass carcass disposal areas.

Management Recommendations

Road design is the factor which most likely has the greatest impact on the frequency of vehicle-wildlife collisions. Road specifications designed to keep vehicle speeds at 45 mph or slower may aid in reducing the frequency of road-killed wildlife. Adopting road design standards which keep vehicle speeds at 45 mph or slower would also be in accord with the mission and mandate of the National Park Service to preserve and protect park wildlife while providing for the safety and enjoyment of the people.

Road designs which are generally narrower and have more curves than standard highway specifications have kept average vehicle speeds at or below 45 mph in YNP for 80 years. In areas where social or economic factors dictate faster speed limits, other highway design techniques could be used to reduce the frequency of vehicle-wildlife collisions. For example, in Florida, fencing and specially-constructed highway underpasses have been used successfully to accommodate wildlife movements across highways (Foster and Humphrey 1995).

Acknowledgments

We would like to thank the following individuals for assistance in completing this study: Eric Compas of the Yellowstone Center for Resources for spatial analysis of the data; R. Renkin for statistical analysis; Resource Management Coordinators T. Olliff, D. Reinhart, L. Lee, and D. Price who assisted in keeping records of road-killed wildlife; Law Enforcement Rangers P. Anzalone, L. Baracz, M. Busbee, A. Bush, J. Farias Jr., B. Gafney, M. Hardin, D. Hubbard, L. Kortge, R. Mossman, B. Phillips, T. Reid, D. Ross, B. Sadler, D. Semprini, T. Smith, S. Sprouse, K. Young who collected radar speeds from vehicles in the park; and all park employees who reported road-killed wildlife.

References Cited

Bartlett, R.A. 1985. Yellowstone: A Wilderness Besieged. Univ. of Arizona Press, Tucson. 437pp.

Caslick, J. W. 1994. The potential effects of highway rehabilitation on wildlife resources in the Northeast Entrance Corridor of

Yellowstone National Park. U.S. Dept. Inter., Natl. Park Serv., Branch of Natural Resources, Yellowstone National Park. 23pp.

Cole, G. F. 1976. Management involving grizzly and black bears in Yellowstone National Park, 1970-1975. U.S. Dep. Inter., Natl. Park Serv., Nat. Res. Rep. 9. 26pp.

Craighead, J.J., J.S. Sumner, and J.A. Mitchell. 1995. The grizzly bears of Yellowstone: Their ecology in the Yellowstone ecosystem, 1959-1992. Island Press, Covelo, CA. 535pp.

Culpin, M.S. 1994. The history of the construction of the road system in Yellowstone National Park, 1872-1966. Historic resource study Volume I. Sel. from the Division of Cultural Resources. Rocky Mountain Region. Natl. Park Serv. 530pp.

Despain, D.G. 1990. Yellowstone Vegetation: Consequences of Environment and History in a Natural Setting. Roberts Rinehart, Inc., Publishers, Boulder, Colo. 239pp.

Dirks, R.A., and B.E. Martner. 1978. The climate of Yellowstone and Grand Teton National Parks. U.S. Dep. Inter., Natl. Park Serv., Nat. Res. Rep. 48pp.

Eberhardt, L. L., and R. R. Knight. 1996. How many grizzlies in Yellowstone? J. Wildl. Manage. 60:416-421.

Foster, M.L., and S.R. Humphrey. 1995. Use of highway underpasses by Florida panthers and other wildlife. Wildl. Soc. Bull. 23:95-100.

Houston, D.B. 1982. The northern Yellowstone elk, ecology and management. MacMillan Publ. Co., Inc. New York, N.Y. 474pp.

Keefer, W.R. 1972. The geologic story of Yellowstone National Park. U.S. Geol. Surv. Bull. 1347. 92pp.

Mattson, D.J., and D.G. Despain. 1985. Grizzly bear habitat component mapping handbook for the Yellowstone ecosystem. Natl. Park Serv.-U.S. For. Serv. Publ. 37pp.

Neu, C.W., C.R. Byers, and J. M. Peek. 1974. A technique for analysis of utilization-availability data. J. Wildl. Manag. 38(3):541-545.

Streubel, D.P. 1989. Small mammals of the Yellowstone ecosystem. Roberts Rinehart, Inc., Publishers, Boulder, Colo. 152pp.

U.S. Fish and Wildlife Service. 1994. The reintroduction of gray wolves to Yellowstone National Park and central Idaho. Final environmental impact statement. U.S. Dep. Inter., Fish and Wildl. Serv., Helena, Mont. 562pp.

U.S. Geological Survey. 1972. Surficial geologic map of yellowstone National Park. U.S. Geol. Surv., Misc. Geol. Inventory Map I-710.

Zar, J. H. 1974. Biostatistical analysis. Prentice Hall, Inc. Englewood Cliffs, N.J. 620 pp.

Table 1

Number of different species of large mammals* killed by vehicles in Yellowstone National Park, 1989 - 1996.

	Year								
Species	1989	1990	1991	1992	1993	1994	1995	1996	Total
Antelope	1	4	6	2	1	2	1	2	19
Bear	1	1	1	3	1	0	2	2	11
Bighorn Sheep	0	0	0	0	1	0	3	1	5
Bison	7	5	12	7	11	11	11	15	79
Black Bear	0	1	0	2	0	1	1	0	5
Bobcat	0	0	0	0	1	0	0	1	2
Coyote	1	9	3	5	10	19	9	10	66
Elk	50	35	54	34	37	49	52	64	375
Grizzly Bear	0	1	0	0	0	0	0	1	2
Lynx	0	0	0	0	0	0	0	0	0
Moose	11	10	5	11	9	12	10	8	76
Mountain Goat	0	0	0	0	0	0	0	0	0
Mountain Lion	0	0	0	0	0	0	0	0	0
Mule Deer	26	35	40	44	37	51	28	25	286
Raccoon	0	0	0	0	0	1	0	0	1
Whitetail Deer	0	1	0	2	2	2	2	0	9
Wolf	0	0	0	0	0	0	1	2	3
Wolverine	0	0	0	0	0	0	0	0	0
Total	97	102	121	110	110	148	120	131	939

* *Species in which adults can attain a weight of 13.6 kg (30 pounds) or more.*

Table 2
Number of different species of large mammals killed by vehicles in different speed zones in Yellowstone National Park, 1989 - 1996.

	Posted Speed Limits						
Species	15	25	35	40	45	55	Total
Antelope	0	4	8	0	7	0	19
Beaver	0	0	2	1	0	8	11
Bighorn Sheep	0	0	4	0	1	0	5
Bison	0	1	3	1	69	5	79
Black Bear	0	1	0	0	1	3	5
Bobcat	0	0	1	0	1	0	2
Coyote	0	4	4	2	28	28	66
Elk	1	13	23	3	96	239	375
Grizzly Bear	0	0	1	0	1	0	2
Moose	1	0	4	9	24	38	76
Mule Deer	1	19	9	19	182	56	286
Raccoon	0	0	0	0	1	0	1
Whitetail Deer	0	0	0	0	5	4	9
Wolf	0	0	0	0	2	1	3
Total	3	42	59	35	418	382	939

[a] *Species in which adults can reach a weight of 13.6 kg (30 pounds) or more.*

Table 3
Proportion of large mammals killed by vehicles in different speed zones in Yellowstone National Park, 1989 - 1996.

Speed Limit	Miles of Roads	% of Total Roads	Number of Road-kills	% of Total Road-kills
15	1.1	0.4	3	0.3
25	18.6	7.0	42	4.5
35	24.9	9.3	59	6.3
40	24.5	9.2	35	3.7
45	178.3	66.6	418	44.5
55	20.2	7.5	382	40.7
Total	267.2	100.0	939	100.0

Table 4

Number of large mammals[a] killed by vehicles on different road segments within Yellowstone National Park, 1989 - 1996.

	Number of Road-kills								
Road Section	1989	1990	1991	1992	1993	1994	1995	1996	Total
Gardiner - Mammoth	1	1	8	1	3	2	7	8	31
Mammoth - Tower	1	2	5	4	6	6	5	4	33
Tower - NE Ent.	1	5	2	8	5	14	7	14	56
Mammoth - Norris	1	3	6	7	8	4	4	5	38
Tower - Canyon	2	2	0	5	0	2	1	4	16
Norris - Canyon	6	2	5	9	3	11	8	5	49
Canyon - F.B.	6	4	9	9	4	7	4	8	51
F.B. - East Ent.	6	4	5	8	3	4	4	3	37
F.B. - West Thumb	3	7	6	5	4	7	2	2	36
West Thumb - S. Ent.	8	7	7	6	14	9	11	10	72
Norris - Madison	2	1	3	1	3	3	2	3	18
Madison - West Ent.	3	8	10	7	18	16	10	7	79
U.S. Highway #191	54	54	52	36	34	58	48	47	383
Madison - O.F.	3	2	3	4	3	4	1	6	26
O.F. - West Thumb	0	0	0	0	2	1	5	4	12
Bechler Road	0	0	0	0	0	0	0	0	0
Total	97	102	121	110	110	148	120[b]	131[c]	939[b,c]

[a] *Species in which adults can reach a weight of 30 pounds or more.*

[b] *1 additional elk killed by a vehicle on the gravel road from Gardiner, MT to the Reese Creek Boundary.*

[c] *1 additional antelope killed by a vehicle on the gravel road from Gardiner, MT to the Reese Creek Boundary.*

Table 5

Proportion of large mammals hit and killed by vehicles in forested and non-forested cover types in Yellowstone National Park, 1989 - 1996.

	Non-Forested		Forested	
Species	Number of Road-kill	% Total Road-kill	Number of Road-kill	% Total Road-kill
Antelope	17	89	2	11
Beaver	4	36	7	64
Bighorn Sheep	5	100	0	0
Bison	45	57	34	43
Black Bear	1	20	4	80
Bobcat	2	100	0	0
Coyote	44	67	22	33
Elk	245	65	130	35
Grizzly Bear	0	0	2	100
Moose	23	30	53	70
Mule Deer	60	21	226	79
Raccoon	0	0	1	100
Whitetail Deer	4	44	5	56
Wolf	1	33	2	67
Total Road-kill	451	48	488	52
Cover Type Total	85 mi	32	183 mi	68

Table 6.
Number of animals hit and killed by vehicles in different cover types along major roads in Yellowstone National Park, 1989 - 1996.

	Cover Type[a]																			
Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Antelope	0	0	0	0	0	17	0	0	0	0	0	1	1	0	0	0	0	0	0	0
Beaver	0	0	0	1	1	4	1	0	0	0	0	0	1	0	0	0	0	0	0	3
Bighorn Sheep	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bison	1	0	0	14	3	45	2	0	0	0	0	0	0	0	0	0	4	0	0	10
Black Bear	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Bobcat	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coyote	0	0	1	8	0	44	1	0	1	0	0	0	1	0	0	0	0	0	1	9
Elk	0	0	0	58	3	245	10	0	1	0	0	3	7	0	0	1	5	0	0	42
Grizzly Bear	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Moose	0	0	1	14	5	23	9	0	0	0	0	0	2	1	0	0	2	0	0	19
Mule Deer	0	0	3	65	9	60	46	0	2	0	0	5	10	1	2	1	30	2	1	49
Raccoon	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Whitetail Deer	0	0	0	2	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Wolf	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	2	0	6	165	22	451	71	0	4	0	0	9	22	2	2	2	41	3	2	135

[a] Cover types are described in the study area section of this report.

Table 7.
Population estimates for large mammals in the Yellowstone area.

Species	Population Estimate	# of Road-kills 1989-1996	Average Road-kill/year	% of Pop. killed/year	Population Estimate Source
Antelope	210	19	2.4	1%	J. Mack
Beaver	300	11	1.4	<1%	D. Smith
Bighorn Sheep	200-300	5	0.6	<1%	K. Legg K. Ostovar
Bison	2,200	79	9.9	<1%	J. Mack
Black Bear	500-650	5	0.6	<1%	Cole 1976
Bobcat	Uncommon	2	0.3		K. Murphy
Coyote	800-1,000	66	8.3	1%	B. Crabtree
Elk	31,000	375	46.9	<1%	J. Mack
Grizzly Bear	280-610	2	0.3	<1%	Eberhardt and Knight 1996
Moose	1,000	76	9.5	<1%	D. Tyers
Mule Deer	2,000	286	35.8	2%	Houston 1982
Raccoon	Rare	1	0.1		
Whitetail Deer	Unknown	9	1.1		
Wolf	90-95	3	1.5	2%	D. Smith