An Assessment of Road Impacts on Wildlife Populations in U.S. National Parks

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Abstract

Current United States National Park Service management is challenged to balance visitor use with the environmental and social consequences of automobile use. Wildlife populations in national parks are increasingly vulnerable to road impacts. Other than isolated reports on the incidence of road-related mortality, there is little knowledge of how roads might affect wildlife populations throughout the national park system. Researchers at the Western Transportation Institute synthesized information obtained from a system-wide survey of resource managers to assess the magnitude of their concerns on the impacts of roads on park wildlife. The results characterize current conditions and help identify wildlife-transportation conflicts. A total of 196 national park management units (NP units) were contacted and 106 responded to our questionnaire. Park resource managers responded that over half of the NP units' existing transportation systems were at or above capacity, with traffic volumes currently high or very high in one quarter of them and traffic expected to increase in the majority of units. Data is not generally collected systematically on road-related mortality to wildlife, yet nearly half of the respondents believed road-caused mortality significantly affected wildlife populations. Over one-half believed habitat fragmentation was affecting wildlife populations. Despite these expressed concerns, only

36% of the NP units used some form of mitigation method to reduce road impacts on wildlife. Nearly half of the respondents expect that these impacts would only worsen in the next five years. Our results underscore the importance for a more systematic approach to address wildlife-roadway conflicts for a situation that is expected to increase in the next five to ten years.

Keywords - Data collection, habitat fragmentation, mitigation, mortality, national park, survey, road ecology, road network, transportation, questionnaire, wildlife management

Introduction

"...to promote and regulate the use of the...national parks...which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." (National Park Service Organic Act, 16 U.S.C.1.)

Overview of wildlife-transportation issues

Currently, public roads have direct ecological effects on an estimated one-fifth of the area of the United States (U.S.) with the ‘road-effect zone’ extending hundreds of meters from the road itself (Forman 2000). These effects include habitat loss, degradation and fragmentation; direct wildlife mortality; and road avoidance behaviors by wildlife (Andrews 1990, Bennett 1991, Forman and Alexander 1998). Further, wildlife-vehicle collisions affect the safety of drivers; nation-wide, deer (*Odocoileus spp.*) - vehicle collisions has been estimated at 720,000-1.5 million annually (Conover 1995, Romin and

Bissonette 1996). More recent data by State Farm Insurance indicate that nationally there are approximately 1,000,000 wildlife-vehicle collisions per year based on the number of claims for collisions with deer, elk (*Cervus elaphus*), and moose (*Alces alces*) and the company's proportion of the market share of each state's auto insurance policies (Miles 2006).

During the next 25 years, significant growth and changes in the nation's economy and population are expected to pose major new challenges for transportation and the environment (TRB 2002). In some areas of the U.S. today, roads are a serious obstacle to maintaining ecological connectivity and a threat to the long-term persistence of key wildlife populations (Noss and others 1996, Sweanor and others 2000, Gibbs and Shriver 2002, Epps and others 2005), and may significantly affect wildlife population demographics (Gibbs and Steen 2005).

Adverse road effects are amplified with increasing road size (Fahrig and others 1995, Lovallo and Anderson 1996), speed limits (Gunther and others 2000), and traffic volume (Seiler 2003, Waller and Servheen 2005). For every kilometer (0.62 mile) of highway construction, an estimated 644 hectares (1591 acres) of land is converted from its original vegetative cover or made available for further development, cumulatively resulting in a significant loss of habitat to wildlife (Wolf 1981). Wildlife populations using areas adjacent to roads face increased mortality risk due to collisions with vehicles (Mumme and others 2000).

Populations of threatened or endangered species and migrating species are especially vulnerable to road mortality (Kline and Swann 1998, Lode 2000, Aresco 2003). The habitat fragmentation effects of roads can isolate wildlife populations unwilling or unable to cross roads (Wayne and others 1992, Gerlach and Musolf 2000), while increased noise, pollution, and edge effects can make habitat less favorable for many species (Chomitz and Gray 1996). Population densities for large mammals tend to be lower within 100-200 m of roads (Lyon 1983, Yost and Wright 2001, Rowland and others 2000, Chruszcz and others 2003). Other road effects include habituation of wildlife to humans resulting in increased human-wildlife encounters (Mattson and Blanchard 1992, Olson and others 1997, Gibeau 1998).

An emerging area of interest is the effects of roads on fragmenting wildlife populations. A study of bobcat (*Lynx rufus*) and coyote (*Canis latrans*) populations affected by a busy southern California freeway indicated that although individuals successfully crossed the highway, they did not always contribute to gene flow through reproduction (Riley and others 2006). The home ranges of these two territorial species, abutted, but did not cross the highway, resulting in significant genetic differentiation between populations on either side (Strasburg 2006).

U.S. National Park system and wildlife-transportation issues

There were more than 273 million recreational visits to U.S. National Parks in 2005 with projections of nearly 270 million and 268 million in 2006 and 2007, respectively (National Park Service 2005). Much of the public's access within these parks is provided by an estimated 8855 kilometers (5500 miles) of paved roads and 7245 kilometers (4500 miles) of unpaved roads. There are many additional roads, paved and unpaved, that run adjacent to, access, or pass through national parks that are maintained by state and local agencies. The U.S. National Park Service (NPS) also has 115 alternative transportation systems in 99 parks, such as shuttles or buses, although 34 of these are water-based

(National Park Service 2007a). This surface transportation system provides the American public with a variety of options for visiting national parks via motorized transport.

By providing protection and habitat for nearly one-quarter of the threatened and endangered species in the U.S., national parks are important conservators of biodiversity (National Parks Conservation Association 2004). In addition to preserving threatened and endangered species, the NPS is mandated to protect all resource values as well as provide for visitor enjoyment (National Park Service 2003). These dual roles are often difficult to balance as individual park visitation levels increase, transportation systems are strained and increased recreational use adds pressure on natural systems (Truett and others 2002, Kelly 2003).

National park wildlife populations are increasingly vulnerable to road impacts. From 1989 through 2005 there were 116,000 vehicle collisions documented in the national parks. Approximately 10 percent of these crashes were wildlife-vehicle collisions, they accounted for 12,577 of the reported crashes from 1989 through 2006 (National Park Service 2007b). Traffic-related mortality of wildlife is a concern in several national parks (Bernardino and Dalrymple 1992, Rosen and Lowe 1994, Kline and Swann 1998, Hawes 2000, Burson and others 2000). Research suggests that increasing bus traffic on the Denali park road has affected caribou (*Rangifer tarandus*) and grizzly bear (*Ursus arctos*) movements (Singer and Beattie 1986, Yost and Wright 2001). Even at low speeds, heavy traffic has been known to block animal movements in parks such as Yellowstone and Great Smoky Mountains (Gunther and others 2000). Other road-related impacts include the habituation of wildlife to food from passing vehicles and invasion of non-native plant species (Tyser and

Worley 1992, Gibeau 2000, Strittholt and Dellasala 2001, National Park Service 2003, Hansen and Clevenger 2005).

Wildlife populations within national parks are not necessarily more protected than those residing outside their boundaries (Newmark 1995, Parks and Harcourt 2002). Some parks can have wildlife road mortality rates in the tens of thousands (Kline and Swann 1998) with significant impacts on certain populations (e.g. moose: Bangs and others 1989; snakes: Bernardino and Dalrymple 1992, Rosen and Lowe 1994; large mammals: Gunther and others 1998). Canadian parks lose hundreds to thousands of animals each year (Damas and Smith 1982). Other than isolated reports on incidences of traffic-related wildlife mortality, there is little knowledge of how roads might affect wildlife populations in U.S. national parks and adjacent lands. Mortality, road-effect zones and habitat fragmentation effects have been the focus of few studies in national parklands. However, Glacier National Park, Montana, has invested in mitigation measures to allow mountain goats (*Oreamnos americanus*) to safely cross under a busy park road to access a mineral lick (Singer and Doherty 1985). Park studies of road impacts have been primarily focused at the level of individuals, whereas population- and ecosystem/community-level impacts have not been contemplated to our best knowledge. A synthesis of information obtained from a system-wide survey of resource managers in U.S. national parks could provide information capable of characterizing current conditions and help identify future wildlife-transportation conflicts and potential mitigation measures in these important landscapes.

The purpose of this study was to assess the degree to which park resource managers were concerned about road impacts on wildlife populations in NPS management units (NP units). By surveying park managers we attempt to qualitatively assess the magnitude of their concern. An effective identification and assessment of wildlife issues involving transportation will help the NPS gauge the ecological impact of roads systematically.

The specific objectives of this study were to survey NPS staff responsible for resource conservation to (1) obtain information characterizing their NP unit's road system, (2) describe data collection practices and estimates of the extent of road impacts affecting wildlife groups, (3) identify whether mitigation practices are being used to reduce impacts to wildlife, and (4) assess future park transportation trends and potential impacts to wildlife populations.

The findings of this survey will fill an important gap in knowledge about the broad impacts of public roads on wildlife throughout the national park system. Further, this synthesis characterizes current and future wildlife-transportation issues so that proper planning for mitigation measures can be anticipated and parks ultimately managed for sustainable transportation to safely accommodate the visiting public while providing for the long-term persistence of viable wildlife populations. Lastly, it should be noted this study is based on qualitative information based on NPS employee perceptions, therefore further analyses may be needed to better quantify and understand key findings.

Methods

We identified 388 NP units to include in our survey; however, only 196 (51%) had public access roads. For these 196 NP units we created a contact list from a NPS employee directory that consisted of one park service employee per NP unit. Questionnaires were sent via electronic mail to the park service employee that we estimated could best answer

questions about wildlife and resources for his or her NP unit; this was generally the resource management specialist or the superintendent if a particular unit was small.
We requested information on the following four main areas:

Background information regarding the survey participant's experience in the NP unit and its road network (e.g., length of public roads, posted speed limits, traffic volumes, road construction history, road capacity, existence of a public transportation system, and location of the nearest U.S. Interstate highway).

Data collection and management – Assessment of data collection and management of traffic-related mortality of five wildlife groups (amphibians, reptiles, large herbivores, large carnivores, small/medium-sized mammals) and studies of habitat fragmentation caused by park roads. Respondents were asked for which wildlife group they had data regarding road-related wildlife mortality and habitat fragmentation. Additionally, the survey requested quantitative data on who reported road-kills and how the effects of habitat fragmentation caused by roads were assessed.

Wildlife-transportation conflicts – The survey asked respondents to characterize road impacts on wildlife populations by direct mortality, habitat fragmentation, habitat loss, human habituation, and risks to human safety. They were also requested to assess the respective magnitude of these same factors within and outside of the NP unit. In addition, we wanted NPS experts to estimate the extent of road-related mortality and habitat fragmentation on the five wildlife groups.

Mitigation practices - Respondents were asked whether mitigation practices were being used in their respective NP unit, what they consisted of and if the measures were monitored and evaluated for their effectiveness.

Survey data from each responding NP unit were entered in a Microsoft® Excel spreadsheet and summary statistics were generated. The entire questionnaire with methodological details can be found in Appendix A, and the list of NP units that responded to the survey is Appendix B.

Results

Background information

Of the 196 disseminated surveys, we received 106 completed surveys for a 54% response rate. Nine respondents indicated the survey was not applicable to their situation. Of these nine who responded but did not complete a survey, three were National Historic Trails that cross over several state boundaries, five were National Heritage Areas or Corridors that have a combination of private and public properties, and one was a working farm. An additional four NP units could not reply as the responsible personnel were not available. Two of the returned questionnaires covered multiple NP units. The Flagstaff Area questionnaire included information corresponding to three units, Sunset Crater Volcano National Monument (NM), Walnut Canyon NM, and Wupatki NM. Also, questionnaires that were sent out to NP units in the Washington, D.C. area (Fort Washington Park, Greenbelt Park, and Suitland Parkway) were consolidated into National Capital Parks-East.

Survey respondents

Of those officials responding, 64% were resource managers, 20% were wildlife/ecology specialists, 14% were park superintendents, and 22% held some other position in the park. Of those responding, 43% had been at their position for 1-5 years, 28% had been at their position for 6-10 years, 23% had been at their position for more than 10 years; and only 7% had held their position for less than 1 year.

National Park Service road system

The NP units represented by this survey range in size from 16 hectares (40 acres) to over 809,371 hectares (2 million acres) with 49% containing less than 34 km (21 miles) of roads, 17% with 34-64 km (21-40 miles) of roads, 11% with 66-129 km (41-80 miles) of roads, 11% with 130-257 km (81-160 miles) of roads, 9% with 259-644 km (161-400 miles) of roads and 3% with more than 644 km (400 miles) of roads.

Ten percent of the respondents indicated their NP unit's entire road system was posted with maximum speeds less than 33 km per hour (21 miles per hours [mph]) and more than half (52%) had all their roads posted with maximum speeds of less than 66 km per hour (41 mph) (Table 1.A.). However, 59% responded that they have at least some road sections in their NP unit with speeds greater than 64 km per hour (40 mph).

Fifty-four percent of the responses indicated that the existing transportation systems in their NP unit were being strained at, or above capacity (Table 1.B.1.). Slightly more than one-third reported their NP unit's transportation systems below capacity. Public transportation was not available in 79% of the NP units (Table 1.B.2.). Traffic volumes were categorized as high or very high in 26% of the NP units with expected increases in traffic expected in 76% of the NP units (Table 1.C.). No new road construction occurred in nearly three-quarters (74%) of the NP units, and 21% had plans for new road reconstruction, resurfacing, or rehabilitation projects (Table 1.D.).

The distance to the nearest U.S. Interstate highway was reported by 74 of the NP unit respondents. Eleven of the 74 reporting had Interstate highways bisecting the NP unit, while 12 had an Interstate highway traversing along a NP unit border or one which was located less than 1.6 km (1 mile) from a border. Sixteen of the respondents had Interstate highways 3-16 km (2-10 miles) away from their NP unit, nine had Interstate highways 18-32 km (11-20 miles) away, 19 had Interstates 34-80 km (21-50 miles) away, and eight had Interstate highways greater than 80 km (50 miles) away. Of the 74 NP units that responded, the furthest reported Interstate highway was 128 km (80 miles) away.

Data collection

Road Mortality

According to national park websites and national park biologists, not all of the five wildlife groups are present in all NP units. Small- and medium-sized mammals are the only wildlife group in all 106 NP units responding to the survey. Amphibians and reptiles are in 104 (98%) NP units, large herbivores are in 100 (94%) NP units, while large carnivores are in only 63 (59%) of the 106 NP units. NP units were most likely to collect road mortality data for large herbivores and large carnivores and least likely to collect data for amphibians (Table 2).

Half of the NP units responding (n=53) collect some kind of road mortality data for wildlife. This information was collected mostly via park rangers or other law enforcement personnel (59%), followed by resource management staff (56%), visitor reports (46%), volunteers or interns (42%), maintenance staff (9%) and researchers (6%).

Habitat Fragmentation

Only 11 NP units responding (10%) collected data on the effects of roads on wildlife habitat fragmentation. The large herbivores wildlife group was the only category for which more than half of the 11 respondents collected habitat fragmentation data (Table 2).

Nine of the 11 (82%) NP units reporting on habitat fragmentation effects of roads used radiotelemetry as their main method of data collection, 6 of the 11 (55%) used field surveys, six (55%) used observational methods, and two (18%) used non-invasive sampling methods. Five of the 11 NP (45%) units that collected data on habitat fragmentation effects used one method, while only two (18%) used all four of the abovementioned methods.

Wildlife Transportation Conflicts

Of the 106 NP units that returned the survey, 51 (48%) responded that road mortality greatly affected wildlife populations within their NP unit. This was exceeded only by habitat fragmentation at 57 (54%). Forty-two (40%) reported that habitat loss strongly affected wildlife, 33 (31%) reported wildlife populations also were strongly affected by habituation to humans-wildlife feeding, and 12 (11%) responded that habitat intrusion by roads was affecting wildlife populations. A further 14 (13%) reported there were other critical issues affecting wildlife populations within their parks. These included high visitor numbers during peak breeding and migration seasons, illegal hunting, disease, increased stress levels from high visitor presence, human development, unleashed dogs, overpopulation and invasion by exotic species.

Most respondents estimated that the impacts of road mortality (54%), human habituation-wildlife feeding (43%), and habitat intrusion (32%) were most significant at the local scale (Table 3). The estimates of the effects of habitat fragmentation and habitat loss were more consistent, but the greater number of respondents put them at the landscape level (30% and 29%, respectively).

With the exception of habitat intrusion and human habituation-wildlife feeding, most respondents reported that all issues were more severe outside of their NP unit on adjacent lands (Table 4). Road-related mortality was believed to be equally or more severe outside of the NP units by 85% of the respondents. The effects of habitat fragmentation were considered by more than two-thirds of the respondents to be more problematic outside park boundaries. Fifty-five (54%) of the respondents reported that habitat intrusion was not a problem on adjacent lands, while 35 (35%) reported that human habituation-wildlife feeding was not a problem, with another 35 (35%) reporting that it was more severe outside of the park.

When asked about factors that contributed to road mortality (respondents could check more than one response), speeding was the most commonly indicated factor (n=65, 62%), although there are no known data on traffic speed. This was followed by unpredictable wildlife behavior (n=64, 61%). Other factors included nighttime driving (n=59, 56%), weather (n=22, 21%), and feeding of wildlife (n=12, 11%). Eighteen respondents added additional factors to the list including: drivers deliberately running over reptiles; wildlife on or crossing roads during migration or other movement events; poorly designed roads; driver inattention; and right-of-way fencing.

Sixty-seven NP units (63%) that responded had wildlife species listed under the Endangered Species Act and of those, 21 (31%) reported that roads in these parks threatened those populations. Twenty-eight NP units (42%) reported that roads had little effect on their endangered populations, while a further 18 (27%) were uncertain if roads posed a threat to the populations. Thirty-eight respondents (37%) indicated that roads bisected critical wildlife habitats in their parks, while 19 (18%) were uncertain about road impacts on their parks critical habitats.

Most respondents (>50%) characterized road mortality and habitat fragmentation effects as a low concern for all five wildlife groups. However, 58% cited the effects of road mortality on small- and medium-sized mammals as medium or high (Table 5).

Mitigation of transportation-wildlife conflicts

Only 38 (36%) of the 106 NP units that responded to the survey reported using some type of mitigation measure to reduce road impacts to wildlife within their NP unit (Table 6.A.). The most common technique used was wildlife signs (53%), followed by speed reduction and public education (both 47%). Other techniques included wildlife crossings and fencing (34% combined). Of the 38 NP units that used mitigation techniques, 17 (45%) used only one technique, 10 (26%) used two techniques, and 11 (29%) used three or more techniques (Table 6.B.).

Twelve of the 38 NP units (32%) with mitigation programs in place monitor the effectiveness of those measures, 19 of 38 (50%) did not monitor, while two NP units were developing monitoring plans; and three did not know whether the measures were being monitored for performance. Of the 12 NP units that monitored the measures, five found them to be effective, one did not, and six had not completed assessments yet.

Seventy-two respondents (68%) reported attending a national park meeting relating to road construction, maintenance or mitigation within their NP unit at least once. If the respondent did not attend a road meeting of this type, there was only a 6% chance that the NP unit would have mitigation programs in place. If the respondent had attended a road meeting, there was a 50% chance that the NP unit had a mitigation program in place.

When asked to predict how road impacts to wildlife will evolve in their NP units over the next five years, 44 respondents (42%) believed that impacts will increase and 48 (45%)

thought they will stay the same. Only 11 (10%) of the respondents thought that road impacts to wildlife in their NP unit would improve over the next five years. Three of the 106 respondents did not answer this question.

Discussion

Just over half (196 of 388) of the National Park Service's management units have public access roads, making wildlife-transportation interactions a broad issue for the Service. This survey on the impacts of roads on terrestrial wildlife had a fairly robust response, with 106 units (of the 196 queried) providing information by replying to our survey. The responding NP units were not significantly different in size than all the NP units with public access roads, allowing us to obtain a representative sample of the NPS system through our questionnaires. Therefore the results of this survey, although based on perceptions, provide insights into transportation-wildlife management issues as the NPS balances the dual goals of providing for visitor use and enjoyment and the protection of wildlife and their habitats.

NPS Road System Characterization

Questions regarding the road transportation system for the NPS highlighted several emerging issues. First, over half (57%) of the NP units' existing transportation systems were perceived to be at or above capacity, with traffic volumes currently high or very high in one quarter of them (26%). This may prove to be problematic given traffic volumes are expected to increase in over three-quarters of the units (76%). Additionally, of those responding, 79% do not have access provided by public transit or alternative transportation systems. Roughly 75% of the units have not upgraded or built new roads in the last 10 years. Infrastructure development for automobile travel is one of the most intractable problems in the National Park system (Dilsaver and Wyckoff 1999).

To address the environmental and social consequences of growing automobile use in the National Park system, the NPS is increasingly considering and implementing alternative transportation systems. The U.S. Congress supported this effort in 1998 with the passage of the Transportation Equity Act for the 21st Century (TEA-21). To meet these infrastructure demands, the NPS established the Alternative Transportation Program in cooperation with the U.S. Department of Transportation to implement its responsibilities under TEA-21. Between 1999-2003, 131 planning projects and 54 alternative transportation construction projects in 75 different NP units were approved costing $46.3 million (U.S. GAO 2002). However GAO estimated that as much as $1.5 billion may be needed to address NPS alternative transportation needs in the next 20 years (U.S. GAO 2002).

NPS Road Effects Data Collection

Nearly half of the respondents (48%) thought road-related mortality strongly affected wildlife populations in their NP unit. Although one-half of the NP units collected some road-related mortality data, only 16% collected data on all the wildlife groups present in their NP unit. The tendency has been to collect data on large-bodied wildlife as it is likely that large animals pose greater threats to motorist safety.

Similarly, limited efforts to record road-related mortality of animals were discovered in a recent survey of the animal road-kill reporting practices of state transportation departments and natural resource agencies in North America (Huijser and others in prep.). Their synthesis showed that only half of the responding natural resource agencies (50%, n=36) and even fewer transportation agencies (37%, n=38) collected road-killed animal carcass data. Their draft report suggests that a national standard for the recording of animal-vehicle collisions would likely stimulate transportation departments and other organizations to collect more spatially accurate data related to road mortality of wildlife. Further, these improved practices would lead to better integration and analyses of the data and ultimately provide useful information to managers. Some transportation agencies are beginning to use Personal Data Assistants (PDA's) in combination with a Geographical Positioning System (GPS) for routine highway maintenance activities (e.g., Washington State; Huijser and others 2006). Standardized data collection in combination with new technological tools could help state agencies and the NPS with data collection that is more efficient, spatially accurate and standardized. This will help develop more informed analyses for transportation-related decision-making.

Over half of the respondents deemed habitat fragmentation by roads to adversely affect wildlife populations within their NP unit. Yet, the NPS does not systematically measure the effects of roads on wildlife habitat fragmentation. Habitat fragmentation data were collected by 10% of the NP units responding to this survey, with none measuring impacts for all of the wildlife groups present in their NP unit. Roads cause changes to wildlife habitat that are more extreme and permanent than other anthropogenic sources of fragmentation (Spellerberg 1998, 2002). When compared to other agents of habitat fragmentation the isolating effect of roads has received surprisingly little attention by conservation biologists and has gone relatively unnoticed (Forman and Alexander 1998). The general lack of published studies and methodologies by the scientific community measuring the effect of habitat fragmentation by roads may explain why few NP units collect this information (Roedenbeck and others 2007); given most respondents deem habitat fragmentation by roads to be problematic.

Transportation-Wildlife Conflicts

Over one-half of the respondents perceived that habitat fragmentation affected wildlife populations and nearly one half believed that road-related mortality impacted wildlife populations in their NP unit. However, when asked in a more wildlife-specific manner, most NPS respondents (>50%) characterized road-related mortality and habitat fragmentation effects by roads as low for all wildlife groups in their NP units, with the exception of the effects of road-related mortality on small- and medium-sized mammals. This may be explained by the fact that respondents acknowledged that roads play a role in direct mortality of wildlife and in habitat fragmentation on NPS lands, but they are not perceived as problematic by most. This may be due to their interpretations of individual-level mortality compared to population-level effects. Wildlife may die on roads but whether the mortality translates to population-level impacts will vary greatly among species and areas. It should be noted that this feedback is based on perception, as only 16% responded that they collect data for all the wildlife groups present in their NP units. The disparity over habitat fragmentation may be explained by the fact that most respondents lacked quantitative data that measured the indirect effects of habitat fragmentation by roads in their NP units on their groups of wildlife.

Protecting endangered species is a higher priority for NPS managers and nearly two-thirds of the NP units responding had wildlife listed under the Endangered Species Act. Of the NP units with endangered species, nearly a third reported that roads in the park threatened those populations, while a further 27% were uncertain as to whether park roads pose a threat to their imperiled populations. This implies that over half of the NP units responding may have roads that adversely impact populations of endangered species. In addition, of the 67 NP units with endangered species, 36% indicated that roads bisected critical habitats for these species. The extent to which roads impact endangered species on NPS lands should be further researched.

Wildlife Conflict Mitigation

Roughly a third of the survey respondents indicated that their NP unit is using at least one type of mitigation technique to reduce road impacts to wildlife. Yet, nearly half of the respondents (48%) thought road-related mortality strongly affected wildlife populations in their NP unit. This dissonance suggests additional mitigation may be needed in NP units throughout the system; however, mitigation strategies will best be applied on a case-by-case basis and vary among species and areas.

Most visitors arrive and travel through national parks by car or bus, so mitigating road impacts to wildlife populations is good stewardship that will help maintain the biological integrity of park ecosystems (Forman and others 2003). Several national parks in Canada and the U.S. have implemented projects that have successfully reduced road-wildlife conflicts. In Banff National Park, Alberta, Canada, seasonal closure of a section of the Lake Minnewanka Loop road was a successful effort to restore connectivity for predator and prey species in critical valley-bottom montane habitat (Duke and others 2001). Highway mitigation measures such as wildlife fencing and crossings have been installed along roads with high traffic densities in national parks such as Everglades, Glacier, and Banff (Singer and Doherty 1985, Foster and Humphrey 1995, Clevenger and Waltho 2000). A more recent example involves the NPS working with Caltrans to mitigate road impacts on wildlife along State Route 23 near the Santa Monica Mountains National Recreation Area. This ongoing project involves installing fencing, clearing culverts and monitoring the effects of these actions before and after construction (R. Sauvajot, pers. comm.).

Other mitigation practices include animal-detection systems (Huijser and McGowen 2003), and novel or moveable signage on low volume roads (Hindelang and others 1999, Messmer and others 1999). Managers in Jasper National Park, Alberta, Canada, introduced 70 kph (43 mph) “slow down for wildlife” zones in three areas of the park and monitoring proved them to be effective for elk, deer and moose, but not for bighorn sheep, *Ovis canadensis* (Bertwistle 2001).

More than two-thirds of the respondents reported attending a meeting related to road construction, maintenance or mitigation within their NP unit at least once. If the interviewee did attend a road meeting, there was a 50% chance of the NP unit having a mitigation program in place. This suggests that additional training and exposure to successful roadway mitigation techniques and successes in other parks may aid parks in developing mitigation strategies and implementing measures.

When asked to predict how road impacts to wildlife will evolve over the next five years, nearly half of the respondents indicated the impacts would increase. An equal proportion of respondents felt that road-related impacts to wildlife would remain at their existing level. Thus, the perception by most Park Service managers suggests that nearly 90% of the respondents expected road impacts to wildlife populations to increase or remain at their existing level. This is consistent with the responses which predicted three-quarters of the management units in the survey will have increased traffic volumes and there will be few new road re-construction projects or other improvements to road infrastructure (21%).

Americans own 243 million motor vehicles and use those vehicles for 89% of all daily travel (Bureau of Transportation Statistics 2005). Travel by car continues to grow faster than the U.S. population or the economy, with more cars, more drivers, and more miles per person each year (National Research Council 1997, 2002). Automobiles allow easier access to national parks and other recreational areas, changing both the length and frequency of travel: for example, in Yosemite National Park the availability of overnight accommodation is capped, yet the number of visitors continues to increase – the result of day-users commuting in cars and tour busses from nearby regions (Forman and others 2003). Over time, increasing vehicle traffic on park roads may alter behavior of individual animals and decrease habitat quality (Gibeau 2000).

Vehicle travel is growing despite the fact the capacity of roads serving the Sierra region and Yosemite National Park are not expanding. The problem of transportation infrastructure development and carrying capacity is prevalent throughout the National Park system. Alternative transportation is being promoted in the NPS as a means of easing the tension between automobiles, roads, and park preservation. Although it is not the ideal solution for all the NPS problems, alternative transportation does hold the potential to mitigate many environmental impacts, including road-related mortality and habitat fragmentation effects, which are associated with transportation infrastructure and a reliance on personal automobiles as the primary means of public access (White 2007).

Summary

Our report indicates that road impacts on wildlife are perceived as major concerns by NPS managers. Increasing the agency's attention to address the impacts of roads on wildlife and ecosystem values is a responsibility consistent with the NPS Organic Act and current NPS policies. Road-related mortality and habitat fragmentation effects by roads are measurable causes of loss to wildlife populations, yet a minority of NP units measure, mitigate, and monitor these impacts on their wildlife populations, including species listed under the Endangered Species Act.

Our report highlights the importance for the NPS to recognize the need for a systematic approach to reducing wildlife-roadway conflicts, particularly because this situation is predicted to deteriorate over the next five to ten years. If road-related impacts to wildlife should deteriorate, it will be important that park managers have reliable information to make informed decisions regarding potential mitigation strategies and conservation actions. Monitoring of wildlife mortality on roads can be improved by using standardized data collection methods with high spatial accuracy (Clevenger and others 2003, Ramp and others 2005). New tools are being used to facilitate data collection in studies researching the effects of roads on wildlife mortality and habitat fragmentation (Waddle and others 2003, Whittington and others 2005, Travaini and others 2007). Lee and others (2006) successfully engaged local citizens in reporting wildlife observations using a web-based GIS mapping tool. Interested citizens were thus able to contribute information that useful for decision-makers mitigating the effects of a highway expansion. There are many low-cost means of reducing road impacts on wildlife (FHWA 2007) and park managers should be kept abreast of the current technologies available. There are many opportunities to assist the NPS in the planning, design and construction of wildlife-sensitive roadways.

It is noteworthy that this study represents the results of a survey based on the perceptions of NPS employees. Perceptions do not always equate with reality, thus further analyses may be needed to better quantify and understand the key findings from our report. Our report, however, does provide strong support from the perspective of NPS professionals, that road impacts to wildlife are a current and future challenge. We are hopeful and confident that this report and other similar efforts will help catalyze improvements by the NPS to provide safe public access while conserving park wildlife resources in perpetuity.

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Table 1. Characteristics of the U.S. National Park Service road system.

A. SPEED LIMITS ON ROADS (Posted speed limit in kilometers per hour (kph))	**NP units responding positively (n=106)**	**Percent of responses**
Road sections >64 kph (>40 miles per hour [mph])	62	58.5
Road sections 33-64 kph (21-40 mph)	86	81.1
Road sections 16-32 kph (10-20 mph)	63	59.4
Road sections <16 kph (<10 mph)	20	18.9
All road sections <16 kph (<10 mph)	2	1.9
All road sections <33 kph (<21 mph)	9	8.5
All road sections <66 kph (<41 mph)	44	41.5
B.1. ROAD SYSTEM CAPACITY		
Existing system below capacity	38	35.8
Existing system at capacity	45	42.5
Existing system above capacity	12	11.3
Uncertain of existing system capacity	11	10.4
B.2. PUBLIC TRANSPORTATION		
Public transportation available	22	20.8
Public transportation not available	84	79.2
C.1. TRAFFIC VOLUMES		
Low	18	17
Moderate	61	57.5
High	15	14.2
Very high	12	11.3
C.2. TRAFFIC VOLUME FORECAST		
Expected to increase	80	75.5
Expected to stay the same	16	15.1
Expected to decrease	0	0
Expected trend unknown	10	9.4
D.1. ROAD CONSTRUCTION		
New construction within last 10 years	27	25.5
No new construction within last 10 years	78	73.6
D.2. ROAD CONSTRUCTION FORECAST		
Planning to build new roads	22	20.8
Not planning to build new roads	75	70.8
Uncertain about plans to build new roads	9	8.5

Table 2. Data collection practices in U.S. National Park units concerning traffic-related mortality and habitat fragmentation effects on five wildlife groups.

Wildlife Group	**NP Units With Group Present** (n=106)	**NP Units Collecting Data**[a]	
		Road Mortality (n=53)	**Habitat Fragmentation** (n=11)
Amphibians	104	23	2
Reptiles	104	26	4
Large Herbivores	100	37	7
Large Carnivores	63	26	5
Small/Medium Mammals	106	30	2

[a] See Appendix A.

Table 3. Estimated spatial scale at which road impacts are impacting wildlife populations in U.S. National Park units.

Impact of roads on wildlife	Local scale (n=106)	Regional scale (n=106)	Landscape scale (n=106)
Road mortality	57 (54%)	16 (15%)	15 (14%)
Habitat fragmentation	28 (26%)	21 (20%)	32 (30%)
Human habituation-wildlife feeding	45 (43%)	9 (9%)	7 (7%)
Habitat intrusion	34 (32%)	5 (5%)	7 (7%)
Habitat loss	25 (24%)	17 (16%)	31 (29%)

Table 4. Estimated degree of severity of road impacts on adjacent lands compared to within U.S. National Park unit lands.

Severity of road impacts on wildlife on adjacent lands (n=106)	No problem	Less severe	Same severity	More severe
Road mortality	13 (12%)	4 (4%)	37 (35%)	48 (45%)
Habitat fragmentation	18 (17%)	1 (1%)	16 (15%)	67 (63%)
Human habituation-wildlife feeding	35 (33%)	15 (14%)	15 (14%)	35 (33%)
Habitat intrusion	55 (52%)	8 (8%)	20 (19%)	19 (18%)
Habitat loss	22 (21%)	2 (2%)	13 (12%)	65 (61%)

Table 5. Estimated road mortality and habitat fragmentation effects on populations of wildlife groups*.

Wildlife group	**Effects of road mortality**			**Effects of habitat fragmentation**		
	Low	Medium	High	Low	Medium	High
Amphibians (n=94)	69 (69.0%)	20 (20.0%)	5 (5.0%)	62 (60.2%)	18 (17.5%)	16 (15.5%)
Reptiles (n=96)	57 (55.9%)	29 (28.4%)	10 (9.8%)	60 (58.3%)	20 (19.4%)	16 (15.5%)
Large herbivores (n=96)	52 (52.0%)	39 (39.0%)	5 (5.0%)	58 (56.9%)	25 (24.5%)	14 (13.7%)
Large carnivores (n=62)	57 (90.5%)	4 (6.4%)	1 (1.6%)	41 (65.1%)	15 (23.8%)	4 (6.4%)
Small/Medium mammals (n=98)	36 (34.0%)	44 (41.5%)	18 (17.0%)	52 (49.1%)	36 (34.0%)	11 (10.4%)

*(n = number of National Park units responding which contain that wildlife group).

Table 6. Types and number of different road mitigation techniques used by U.S. National Park units (if mitigation efforts were in place).

6.A. Type of Mitigation Technique	**NP Units Using Technique (%)** (n= 38)
Wildlife Warning Signs	20 (53%)
Speed Reduction	18 (47%)
Public Education	18 (47%)
Wildlife Crossings	7 (18%)
Fencing	6 (16%)
Road Design	4 (11%)
Road Closures	2 (5%)
Public Transportation	1 (3%)
Other	4 (11%)
6.B. Number of Mitigation Techniques Used	**Number of NP Units (%)** (n=38)
1	17 (45%)
2	10 (26%)
3	6 (16%)
4	2 (5%)
5	1 (3%)
6	2 (5%)

Appendix A: National Park Unit Questionnaire

An Assessment of Road Impacts on Wildlife Populations in U.S. National Parks

This survey is being conducted by the Western Transportation Institute at Montana State University. The purpose of this survey is to gather important information from park officials on the impacts of roads on wildlife populations within the U.S. National Park system. A national park (NP) unit is defined as any land that is designated under the U.S. National Park Service's jurisdiction: National Battlefields, Heritage Areas, Historic Parks, Historic Sites, Lakeshores, Memorials, Monuments, Parks, Parkways, Preserves, Recreation Areas, Refuges, Seashores, and Trails.

While participation in this survey is strictly voluntary, your opinions are very important to this research project. Please return the completed questionnaire via email or fax by July 15, 2004.

Name: ____

National Park Unit: ____

A. BACKGROUND INFORMATION

1. What is your position?
   a) Superintendent
   b) Resource Management Manager
   c) Wildlife Specialist
   d) Other (*Please specify)*: ______________________________

2. How many years have you worked in this position at this NP unit?
   a. less than or equal to 1 year
   b. 2-5 years
   c. 6-10 years
   d. more than 11 years

3. An estimate of the miles of public roads in your NP unit is:
   (Public roads can be paved or unpaved, but excludes service roads).
   a. 0- 20 miles
   b. 21- 40 miles
   c. 41- 80 miles
   d. 81- 160 miles
   e. 161- 400 miles
   f. Other (*Please specify*): ________________________________

4. What proportion of the roads in your NP unit fall within these speed limit categories?
   a. Less than 10 mph _____ % of roads
   b. 10- 20 mph _____ % of roads

c. 21- 40 mph _____ % of roads
d. 40 mph or faster _____ % of roads

5. How would you characterize the average traffic volume on the main roads in your NP unit?
   a. Low (≤ 100 vehicles per day [VPD])
   b. Medium (100-2000 VPD)
   c. High (2000-4000 VPD)
   d. Very High (> 4000 VPD)

6. In the last 10 years, has there been any new road construction in your NP unit?
   a) Yes b) No c) Do not know

7. Are there plans to build new roads in the next 10 to 20 years?
   a) Yes b) No c) Do not know/ Not sure

8. How would you characterize the existing road system and road capacity (or level of service) that is necessary for visitors in your NP unit?
   a. Below capacity
   b. At capacity
   c. Over capacity
   d. Do not know

9. Do you have a public transportation system on the roads to/within your NP unit?
   a) Yes b) No c) Not sure

10. Within the next 10 years, do you project the visitor traffic volume to your NP unit to
   a) Increase b) Decrease c) Remain level d) Do not know/ Not sure

11. Is there an Interstate near the NP unit? If yes, what is the distance from the Interstate to
   the NP unit?
   a) Yes; __________ miles from the NP b) No

B. DATA COLLECTION

12. On which group of wildlife do you collect <u>road-kill</u> data? (*Circle all that apply.)*
   a. Amphibians
   b. Reptiles
   c. Large Herbivores
   d. Large Carnivores
   e. Small/ Medium-sized Mammals
   f. Other (e.g. invertebrates): ___________________________

13. How are wildlife <u>road-kills</u> reported?
   a. Visitor

b. Park ranger/law enforcement
c. Resource management staff
d. Volunteer/interns
e. Other (*Please specify)*: ______________________________

14. On which group of wildlife is data on habitat fragmentation effects of roads collected? (*Circle all that apply)*.
a. Amphibians
b. Reptiles
c. Large Herbivores
d. Large Carnivores
e. Small/ Medium-sized mammals
f. None of the above: data not collected. Please skip to Question 16.

15. How were data on habitat fragmentation effects of roads collected?
a. Field Survey
b. Radiotelemetry
c. Non-invasive sampling
d. Observations
e. Other (*Please specify)*: ______________________________

C. WILDLIFE-TRANSPORTATION CONFLICTS

16. Which of the following issues significantly affect wildlife populations in your NP unit? (*Circle all that apply)*
a. Road mortality
b. Habitat fragmentation (including full or partial barrier effects)
c. Human habituation/ animal feeding
d. Increase danger/risk to visitors (e.g. habitat intrusion)
e. Habitat loss
f. Other (*Please specify):* ______________________________

17. Estimate the magnitude of each impact using the following scale:
(L) = Local; mainly confined to road segments, like a stretch of road
(R) = Regional; a watershed or size of a small park
(LE) = Landscape and ecosystem-wide: size of a large park
(Use all that apply)

Impacts	Scale (L, R, LE)
Road mortality	
Habitat fragmentation	
Human habituation/animal feeding	
Increase danger/risk to visitors	
Habitat loss	
Other	

18. Do the impacts listed below occur beyond your NP unit boundary in adjacent lands? If

yes, to what degree of severity? If no, skip to Question 19.

(*Check one severity box for each impact)*.

	Degree of Severity			
Impacts	More severe	Less severe	Same	Not applicable
Road mortality				
Habitat fragmentation				
Human habituation/animal feeding				
Increase danger/risk to visitors				
Habitat loss				
Other				

19. Are there any threatened, endangered, or locally extinct vertebrate species within your NP unit?

a) Yes (go to Question 20)
b) No (go to Question 21)
c) Not aware of any in my NP unit

20. Are any of these wildlife populations threatened by roads?

a) Yes b) No c) Not sure/ do not know

21. What causes do you believe contribute to most road-related mortality of wildlife? *(Circle all that apply).*

a. Weather conditions
b. Speeding
c. Nighttime driving/poor visibility
d. Unpredictable animal behavior
e. Human feeding of wildlife
f. Other (*Please specify)*: ________________________________

22. With regard to wildlife populations in general, how severe would you characterize road-related mortality to the following 5 groups?

[*Indicate (L) for Low or None; (M) for Moderate; (H) for High; and (NP) for Not Present*].

Animal group	Severity (L, M, H, or NP)
Amphibians	
Reptiles	
Large Herbivores	
Large Carnivores	
Small/ Medium-sized mammals	

23. Do roads in your NP unit cut through critical habitat of some species?

a) Yes b) No c) Do not know

24. With regard to wildlife populations in general, how severe would you characterize habitat fragmentation effects of roads for the following 5 groups?

[*Indicate (L) for Low or None; (M) for Moderate; (H) for High; and (NP) for Not Present*].

Animal group	Severity (L, M, H, or NP)
Amphibians	
Reptiles	
Large Herbivores	
Large Carnivores	
Small/ Medium-sized mammals	

25. Describe what single road or road system in your park has the greatest impact on single or multiple wildlife populations in your park. Describe the road in terms of number of lanes, traffic volume, traffic speed, feeding of wildlife, etc. Indicate N/A if not applicable.

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D. MITIGATION PRACTICES

26. Have mitigation practices been used to reduce road impacts to wildlife in your NP unit?

a) Yes (go to Question 27)
b) No (go to Question 30)
c) Not sure

27. What types of mitigation techniques were employed? (*Circle all those that apply*).

a. Animal passages (over or under roads)
b. Fencing
c. Road design
d. Speed reduction
e. Public transit (shuttle buses, light rail, etc.)
f. Wildlife signage
g. Public education and awareness campaigns
h. Other (*Please specify)*: ____________________________________

28. Are the mitigation techniques being monitored for performance?

a) Yes b) No c) Monitoring plans are being developed d) Not sure

29. Were the mitigation techniques judged to be effective?

a) Yes b) No c) Do not know yet d) Not sure

Please explain the basis for your answer (observational studies, subjective opinion, anecdotal information, etc.).

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30. During your employment with the U.S. National Park Service, have you participated in a national park meeting (either internal or external) relating to road construction, maintenance, or mitigation within your NP unit?

a) Yes b) No

31. Please describe how you expect road impacts to wildlife will evolve in your NP unit in the next 5 years (get better, become worse, or stay the same).

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Thank you for your information and opinions. Please return your completed questionnaire by July 15, 2004, via email at WTIOFCAD@coe.montana.edu or fax to 406-994-1697.

Appendix B: List of National Park units that responded to survey

Acadia National Park (NP)
Agate Fossil Beds National Monument (NM)
Allegheny Portage Railroad National Historic Site (NHS)
Antietam National Battlefield (NB)
Appomattox Court House National Historic Park (NHP)
Badlands NP
Big Hole Nat. Battlefield
Big South Fork Nat. River & Recreation Area
Big Thicket National Preserve
Bighorn Canyon National Recreation Area
Blue Ridge Parkway
Bryce Canyon NP
Buffalo National River
Cabrillo Nat. Monument
Canaveral National Seashore
Canyonlands NP
Cape Cod National Seashore
Cape Hatteras National Seashore
Catochin Mountain Park
Chiricahua Nat. Monument
City of Rocks National Reserve
Colorado Nat. Monument
Cowpens National Battlefield
Crater Lake NP
Craters of the Moon Nat. Monument
Cumberland Gap Nat. Historical Park
Delaware Water Gap National Recreation Area
Devils Postpile Nat. Monument
Everglades NP
Flagstaff Area NM (Sunset, Walnut Canyon, Wupatki)
Florissant Fossil Beds Nat. Monument
Fort Necessity Nat. Battlefield
Fort Pulaski Nat. Monument
Fort Washington Park (NACE)
Fossil Butte Nat. Monument
Frederick & Spotsylvania Nat. Military Park
Gateway Nat. Recreation Area
George Washington Birthplace Nat. Monument
George Washington Memorial Parkway
Gettysburg Nat. Military Park
Glacier NP
Golden Spike Nat. Historic Site
Grand Canyon NP
Great Basin NP

Great Smoky Mountains NP
Guadalupe Mountains NP
Hagerman Fossil Beds Nat. Monument
Hampton Nat. Historic Site
Harper's Ferry Nat. Historic Park
Herbert Hoover Nat. Historic Site
Hopewell Furnace Nat. Historic Site
Horseshoe Bend Nat. Military Park
Hot Springs NP
John Day Fossil Beds Nat. Monument
Kenai Fjords NP
Klondike Gold Rush Nat. Historical Park
Lake Mead National Recreation Area
Lake Roosevelt National Recreation Area
Lassen Volcanic NP
Lava Beds Nat. Monument
Lyndon Johnson Nat. Historical Park
Manassas Nat. Battlefield Park
Manzanar Nat. Historic Site
Mesa Verde NP
Mississippi Nat. River & Recreation Area
Moores Creek Nat. Battlefield
Mount Rainer NP
Natchez Trace Parkway
Niobrara National Scenic River
Ocmulgee Nat. Monument
Olympic NP
Organ Pipe Cactus Nat. Monument
Padre Island National Seashore
Petersburg National Battlefield
Petrified Forest NP
Pictured Rocks Nat. Lakeshore
Pipe Spring Nat. Monument
Point Reyes Nat. Seashore
Pu'ukohola Heiau Nat. Historic Site
Redwood NP
Rocky Mountains NP
Saguaro NP
Salinas Pueblo Missions Nat. Monument
San Antonio Missions Nat. Historical Park
Santa Monica Mountains Nat. Recreation Area
Saratoga Nat. Historic Park
Scotts Bluff National Monument
Sequoia & Kings Canyon NP
Shiloh Nat. Military Park
Sleeping Bear Dunes Nat. Lakeshore

Stones River Nat. Battlefield
Theodore Roosevelt NP
Thomas Stone Nat. Historic Site
Timucuan Ecological & Historic Preserve
Vicksburg Nat. Military Park
Voyageurs NP
Whiskeytown Nat. Recreation Area
White Sands Nat Monument
Wind Cave NP
Yellowstone NP