Wildlife – Roadway Interactions

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INTRODUCTION

Roads are an important component of the modern landscape. They support the flow of people, goods, and services within towns and across continents. Approximately 4 million miles of roads covering 60,000 square miles of land surface have been constructed in the conterminous United States alone (Forman 1995, Forman and Hersperger 1996). This extensive development has a substantial impact on wildlife habitat quality and connectivity, and poses significant threats to long-term biological diversity. Roads impact wildlife populations and distribution through changes in habitat quantity and quality, direct mortality from vehicle collisions, and division of once large populations into smaller groups at greater risk of extinction and genetic change (Forman 1995; Leedy 1975a, 1975b). Wildlife also has a substantial impact on highway safety. Every year, property damage from animal/vehicle collisions costs more than 1 billion dollars and about 100 people die in these accidents (Conover et al. 1995, Cook and Daggett 1995).

A number of excellent reviews on various aspects of this subject are available (Forman 1995, p. 159-172; Foster and Humphrey 1992; Groot Bruinderink and Hazebroek 1996; Jalkotzky et al. 1997; Leedy 1975a, 1975b; Putman 1997). Our primary purpose in this paper is to provide an updated and comprehensive bibliography of the published and unpublished literature on roadway and wildlife interactions and, secondarily, to provide a concise review of wildlife and roadway interactions, discuss techniques to minimize negative impacts, and identify common strategies for improving highway safety regarding animal/vehicle collisions. Particular emphasis will be on techniques to provide animal passage and limit population fragmentation effects. This paper and the associated bibliography (Appendix A) will contribute to the dissemination of the extensive knowledge that has been gathered on this subject. The bibliography also is available from the authors in a computer file format that can be readily imported into bibliography management software to allow keyword and other searches of titles and abstracts.

ECOLOGICAL FUNCTIONS AND EFFECTS

Roads or road corridors function ecologically as: 1) habitat for the species and their predators and competitors, 2) sources of contaminants and human disturbance, 3) conduits for movement or range expansion, 4) partial or complete filters to animal movement , and 5) mortality agents (Forman 1995). These functions impact wildlife populations and subsequent viability by changing the amount, spatial distribution, and quality of habitats; by changing patterns of interaction between competitors, predators, and prey; and by mortality resulting from vehicle collisions or human access to animals (e.g., shooting, trapping). The combination of these effects can result in reduced wildlife populations and isolation of the remaining animals in smaller groups that are more prone to extinction and genetic change than larger contiguous populations.

Habitat

Substantial amounts of wildlife habitat have been converted into pavement or early-successional vegetation in right-of-ways. Forman and Hersperger (1996) calculated that roads cover approximately 2% of the conterminous United States (about 60,000 square miles). This direct loss of habitat is significant in mountainous areas where roads tend to be concentrated in lower elevation valley bottoms that provide the most productive wildlife habitats (Woods and Munro 1996). Roadsides, however, also can provide unique habitat characteristics associated with early-successional vegetation and edges.

Early-successional habitats: Roadside verges are often maintained in early successional vegetative communities for safety concerns and ease in highway maintenance. Early successional roadside communities provide habitat for a variety of animals, particularly small mammals (e.g., Haner et al. 1996, Schwartz et al. 1994, van der Reest 1992), and birds (Hsu and Peterle 1989). Woodchucks in Ontario were found to occur at higher densities in habitats associated with interstate highways and interchanges than in any other habitats (Woodward 1990).

Edge habitats: Roads in forested landscapes provide breaks in the forest cover which create conditions suitable for wildlife associated with edge and grassland habitats (Hanowski and Niemi 1995). Road associated edge habitats can increase local species diversity, however, species occupying early successional roadside habitats are often common elsewhere (King et al. 1996). Adams and Geis (1981a, 1981b, 1983, 1984) found grassland and generalist birds and small mammals preferred right-of-way vegetation in a survey of wildlife associated with highways in Virginia, the Carolinas, Illinois, and Oregon. Burke and Sherburne (1982) detected a change in bird species composition due to highway construction through forested habitat in northern Maine (see also Maine Cooperative Wildlife Research Unit 1983).

Many species associated with roadside edge habitats are undesirable. Cowbirds are more common along roadside edge habitat than in interior forests (Brittingham and Temple 1983, Camp and Best 1993). Even narrow roads that divide interior forests provide habitat for cowbirds and nest predators and can contribute to substantial negative effects on interior forest songbird populations (Rich et al. 1994, Robinson and Wilcove 1994). In Australia, the exotic, toxic cane toad was found to occur at higher densities along roads and vehicle tracks than in adjacent forested habitats (Seabrook and Dettmann 1996).

Foraging opportunities: Early successional roadside habitat can provide foraging opportunities for a variety of species. Black bears in North Carolina exploit berries growing along low volume or closed roads (Beringer et al. 1988). Open areas above roads can provide foraging opportunities for bats, particularly where street lamps attract concentrations of insect prey (Blake et al. 1994, Crome and Richards 1988, Rydell 1992).

Ungulates (notably deer) feed on grassy roadsides, especially in forested landscapes or other areas where forage availability may be limited (e.g., Bellis and Graves 1971, Carbaugh et al.

1975). Roadside habitats can be attractive for ungulates because cover is often available adjacent to forage and large predator density is usually reduced in the vicinity of open roads (e.g., Mace et al. 1996, Mech et al. 1988).

Forage can be more available along roads and railroads in the winter months due to plowing and accelerated snow melt. Rabbits have been documented using roadsides (Kline 1965), and moose using railroad verges (Andersen 1991) during deep snow periods because of superior forage availability.

Small and medium sized mammalian predators and raptors may regularly use roadsides because of the availability of small mammals (King et al. 1996) and the ease of foraging along linear strips of edge habitat (Bergin et al. 1997, Marini et al. 1995, Stanley 1991). Kavanagh and Murray (1996) found that a radio-collared masked owl spent 56% of its time within 100 meters of ecotones along roads and fields. Burrowing owls in Colorado tended to locate burrows closer to roads (Plumpton and Lutz 1993). Ferruginous hawks in Montana that nested closer to roads produced more young than other hawks (Zelnak and Rotella 1997).

Scavengers often feed on carrion associated with roadways (Conner and Adkisson 1976). Ravens were found to be more common near roads and other linear right-of-ways in the Mojave Desert (Knight and Kawashima 1993, Knight et al. 1995). A variety of snake species also have been documented foraging on road-killed carcasses (Bedford 1991a, 1991b; Hamel 1996).

Residual vegetation in developed landscapes: In some developed landscapes, public lands associated with linear right-of-ways can be the only remaining (and best-connected) patches of residual natural vegetation (Bennett 1990, 1991; Daniels 1994). Roadside habitat areas have become central components of conservation planning in many areas including Australia (Cale 1990, Newby and Newby 1987, Stone 1992), South Africa (Dawson 1991), the United Kingdom (Way 1970, 1977), Europe (Darrall 1987, Opdam et al. 1994), and the United States (Adams and Dove 1989, Little 1990, Stevenson 1996, Warner 1992).

Residual cover along roadsides can provide habitat for nesting birds, especially in agricultural landscapes (Arnold and Weeldenburg 1990, Berg and Part 1994, David and Warner 1981, Horkel et al. 1981, Kartanas 1996, Kilbride et al. 1992, Leach and Recher 1993, Warner et al. 1992). Camp and Best (1993) documented 35 bird species in roadside habitats compared to 26 species in adjacent rowcrop fields. Warner (1992) found that numbers of nests and species increased with roadside width. Some species of birds are also attracted to ornamental roadside plantings (Dowler and Swanson 1982, Jozsef 1980).

During a survey of highway verges and median strips, Munguira and Thomas (1992) documented up to 23 species of butterflies occupying roadside habitat in the United Kingdom. Small mammal use of residual habitats along roads has been documented in Australia (Lindenmayer et al. 1994).

While residual roadside vegetation plays an important part in providing wildlife habitat in developed landscapes, it is important to consider that the quality of roadside habitats are often compromised by road related disturbances including noise (Barrett 1996, Foppen and Reijnen 1994, Reijnen and Foppen 1995), predation (Bergin et al. 1997, Camp and Best 1994, Marini et al. 1995), environmental contaminants (O'Neill and Robert 1985), and human disturbance.

Other habitat characteristics: Roadside excavations and associated soil characteristics can provide unique habitat features for vertebrate and invertebrate wildlife (Banks et al. 1990, Port and Thompson 1980). Demers (1993) found western harvester ants in North Dakota occupying well-drained roadside ditches at a higher rate than they occupied adjacent agricultural lands. Roadside habitat values for carabid beetles also have been investigated (Vermeulen 1993, 1994). Cutbanks and adjacent areas can provide soil conditions suitable for denning and burrow excavation for species such as skunk (Crooks 1994), swift fox (Hines and Case 1991), and burrowing owl (Plumpton and Lutz 1993).

Roads and roadside environments can provide other habitat features as well. Snakes and other reptiles are often attracted to warm, open roadway surfaces (Dodd et al. 1989, Mendelson and Jennings 1992). Amphibians have been documented breeding in puddles on low-volume roads (Adam and Lacki 1993). Caribou in Alaska will sometimes gather on oil drilling gravel pads and road surfaces to avoid mosquitoes and oestrid flies (Pollard et al. 1996a, 1996b). Roads may even provide navigational queues for migrating birds (Franchimont 1993, Greenwood 1989, Mead 1993).

Sources of Contaminates and Disturbance

Roads can be sources of materials, energy, or activity that flow from the road into the surrounding landscape. These flows can affect wildlife distribution and activities in a variety of ways.

Pollutants and contaminants: Highways are a source of chemical pollutants from vehicle exhaust and fluid leakage (Albasel and Cottenie 1985, Ylaranta 1995). These chemicals flow from the road into the adjacent landscape and are often directly or indirectly ingested by animals inhabiting roadside environments (Beeby and Richmond 1987, Clark 1979, Grue et al. 1986, Kostelecka-Myrcha et al. 1997, Spencer and Port 1988). Contamination has not been found to have extensive population impacts on roadside wildlife (Clark 1992), however, there may be local circumstances with substantial impact (Mierau and Favara 1975). Some emission chemicals (notably nitrogen compounds) enhance plant growth and may alter plant community composition (Angold 1997).

A common group of chemicals associated with roads are deicing agents. Introduction of highway salt can have substantial effects on roadside environments (Hofstra and Smith 1984, Kjensmo 1997, Rutter and Thompson 1986). Changes in soil and water salinity can impact amphibians (Pauli 1997). Some species, especially moose, are attracted to the salt

and may make extensive use of roadside salt accumulations (Fraser and Hristienko 1982; Fraser and Thomas 1982; Miller and Litvaitis 1992a, 1992b).
The role of roads as sources of sedimentation in aquatic habitats has been well documented. Unpaved forest roads (Brown and Binkley 1994) and highway construction (Roberts 1995) are common sources of sedimentation.

Roads can be substantial sources of noise (Coulson 1996, Shaw 1996). The negative effects of noise on breeding bird populations have been recognized (Barrett 1996, Benson 1996). Reijnen et al. (1995) found that 60% of woodland species studied in the Netherlands had reduced density closer to high volume roads. Areas of reduced bird density were most closely correlated with highway noise conditions. Highway noise was found to have a significant effect on least Bell's vireo in California (Barrett 1996). Brattstrom and Bondello (1983) found hearing loss and altered behavior patterns in small desert mammals exposed to off-road vehicle noise. Grizzly bears avoided areas where there was noise in the vicinity of a logging operation and hauling road in coastal British Columbia (Archibald et al. 1987).

Human disturbance: Perhaps the greatest impact that roads have on the environment is the presence of humans. After all, roads are designed and built to move people from place to place and inevitably they will have an influence on wildlife. Human disturbance ranges from mortality (e.g., hunting and trapping) to simply causing changes in normal behavior patterns (Gill et al. 1996).

The relationship between ungulate habitat use and human access provided by roads is well documented (e.g., Christensen et al. 1991, Lyon et al. 1985). Poor quality elk habitat has been directly related to open road density (Ager 1994; Thomas 1979, p. 122-123). Deer and moose have been documented avoiding open roads, particularly during hunting season (Boer 1990, Livezey 1991, Rost and Bailey 1979). Poor habitat quality for carnivores also has been clearly tied to human access and open road density. This is especially true for large predators that have historically been perceived as threats to human safety or associated with livestock depredations, notably wolves (Fuller 1989, Mech et al. 1988), grizzly bears (Clevenger et al. 1997, Mace et al. 1996, Mattson et al. 1987, McLellan and Shackleton 1988), and some raptors (Ferrer and Harte 1997). Human access related to open road density also negatively influences habitat use by hunted or trapped carnivore species including black bear (Brody and Pelton 1989, Clark et al. 1993), American marten (Hodgman et al. 1994, Schulz and Joyce 1992), and bobcat (Lovallo and Anderson 1996).

Not all human activities are intentionally intrusive. Non-consumptive recreation activities such as birdwatching or hiking can impact habitat use and behavior patterns (Boyle and Samson 1985, Marzluff 1997).

Road construction and increased access in developing countries can have substantial impact in previously inaccessible areas (Ayers et al. 1991, Boinski and Sirot 1997, Fearnside and de Lima Ferreira 1984). Poaching (Barnes 1996), deforestation (Nelson and Hellerstein 1997), and other negative impacts often accompany greater access and mobility.

Conduit for Movements

Roads are constructed to be conduits for people and products within the landscape. Roads and roadside habitats also provide efficient movement routes for individuals and populations of wildlife as well. Within their home range, small- and medium-sized predators often forage along edge habitats associated with roads (Bergin et al. 1997). Large mammals, including wolves (Groebner and Williams 1988, Singleton 1995, Thurber et al. 1994), mountain lion (Smallwood and Fitzhugh 1995), deer (O'Gara and Harris 1988), black bear (Beringer 1986), coyote (Thurber et al. 1992), and presumably other species, often use low volume or closed roads to move within home ranges.

Roads and roadside habitats also provide dispersal routes for animals moving outside of their home range. Getz et al. (1978) found meadow vole expanding its range through unmowed strips along interstate highways in Illinois. Low volume roads have been noted as dispersal routes for other species including black-tailed prairie dog (Reading and Matchett 1997) and carabid beetles (Vermeulen 1994). Dispersal through roadside habitats can serve an important conservation function when roadside residual vegetation serves to connect native habitat patches (Baker 1996; Bennett 1990, 1991; Daniels 1994; Stevenson 1996).

Due to the nature of most roadside habitats (usually early successional habitats or narrow strips of residual vegetation), the plants and animals that most often find these areas to be suitable for dispersal are early successional or generalist species (Mader 1984). Frequently these species are exotic or undesirable. For example, feral pig habitat use in Australia has been positively associated with the presence of roads (Mitchell and Mayer 1997). Weed propagules are often carried in the undercarriage of vehicles, distributed along the roadside, and disperse into the adjacent landscape (Amor and Stevens 1976, Ayeni et al. 1997, Wilcox 1989).

Filtering Movements and Fragmenting Populations

Roads can restrict the movements of wildlife (Andrews 1990, DeSanto and Smith 1993). Mader (1984) noted that while providing dispersal networks for generalist species, roads represent a barrier to species with narrow habitat requirements. The effects of changed movement patterns on wildlife populations depend on the characteristics of the barrier and the movement being influenced.

Roads act as filters to animal movements in three ways: 1) road visual and auditory disturbance may induce avoidance behavior, 2) the physical characteristics of the roadway may prohibit movement across the road, and 3) direct mortality prevents successful crossing. Filter functions of roadways depend on the species in question, traffic volume, and the design characteristics of the road.

Physical barriers: Certain design characteristics can make roadways impermeable barriers for some species. Roadway characteristics that may influence permeability include curbs, concrete "Jersey" median barriers, steep roadside embankments, fencing, walls, and transitions in habitat structure.

Documentation of the effects of highway median barriers on crossing behavior is limited, but without gaps to provide for passage, the effect of these barriers on roadway permeability for smaller animals is intuitive. Hubbs and Boonstra (1995) assembled a study plan for determining the relationship between median barriers and road kill mortality rates along multiple lane highways in southern Ontario. The study was never funded, but the plan is an excellent resource. Anecdotal stories of small- and medium-sized mammals and birds (particularly waterfowl with broods) being blocked from passage by median barriers in the middle of busy highways are not uncommon.

Roadside fencing is a common technique for reducing animal/vehicle collisions. However, without adequate planning for crossing opportunities (see "Passage structure"), fences can have negative impacts on wildlife populations. Fences that are designed to limit wildlife movements, with an emphasis on migratory ungulates, may reduce collisions but also may affect population dynamics (Falk et al. 1978, Hanna 1982, Ward 1982, Ward et al. 1980).

The transition of habitat conditions, especially from those providing cover to mowed roadside or pavement, can be a barrier for some species. A number of studies have documented barrier effects of lightly used roads or mowed swaths for small mammals (Andreassen et al. 1996, Barnett et al. 1978, Burnett 1992, Garland and Bradley 1984, Oxley et al. 1974, Swihart and Slade 1984, Wolff et al.). Similar effects have been documented for snails (Baur and Baur 1990) and carabid beetles (Mader 1984).

Selective removal of individuals: Direct mortality while crossing roads can have a substantial influence on traditional wildlife movement patterns through learned avoidance or death of individuals inclined to cross dangerous roadways. Reilly and Green (1974) found that deer/vehicle collisions increased substantially when an interstate was built through a deer yard in Michigan, then decreased gradually. Apparently, deer in this population either learned avoidance of the highway or the crossing behavior was removed from the population through selection. Direct mortality can be a severe barrier when associated with seasonal mass migrations of entire breeding populations, as is common for some amphibian species (Ashley and Robinson 1996, Barry and Shaffer 1994, van Gelder 1973).

Behavioral barriers: For some species, the combination of physical roadway barriers, human disturbance associated with roads, and selection from roadway mortality will lead to learned or innate roadway avoidance behaviors. Behavioral avoidance resulting in reduced road crossing has been documented for many species including grizzly bears (Archibald et al. 1987), wolves (Paquet and Callahan 1996), black bears (Beringer et al. 1988, Brody and Pelton 1989), and bobcats (Foster and Humphrey 1992). Other species have been documented to exhibit agitated or hesitant behavior in close proximity to roads (Murphy and Curatolo 1986, Pedevillano and Wright 1987).

Population fragmentation: The filter effects of roadways can reduce, or in some cases, prevent movement across the landscape. Roadway barriers may separate a single larger population into two or more smaller populations. In general, smaller populations are more at risk of extinction due to random changes in the environment, population structure, and genetic composition of the population (Hanski and Gilpin 1997). Barrier effects also will impact a species ability to recolonize a habitat patch should a subpopulation become extinct.

The theoretical literature addressing population fragmentation effects and metapopulation dynamics is well developed (e.g., Andren 1994, Bascompte and Sole 1996, Doak et al. 1992, Hanski and Gilpin 1997, Hansson 1991, Saunders et al. 1991, Verboom et al. 1993), and the potential for transportation networks to impact animal dispersal, particularly for wide ranging carnivores, is broadly acknowledged (Paquet and Hackman 1995, Reudiger 1996, Servheen et al. 1997). Beier (1993) found that interstate and state highways limited the quality of corridors for cougars in southern California and contributed to demographic instability in this population. Gibeau et al. (1996) found limited movement of grizzly bears across the Trans-Canada Highway in Banff National Park. When combined with secondary residential, commercial, and resource extraction development, highways can be the central feature of significant “fracture zones” for species sensitive to human disturbance, such as grizzly bears (Apps 1997, Mietz 1994, Servheen and Sandstrom 1993).

A few studies of small mammals address the degree to which roads limit animal movements (Burnett 1992, Garland and Bradley 1984, Oxley et al. 1974, Swihart and Slade 1984) or cause genetic divergence of subpopulations (Merriam et al. 1989, Richardson et al. 1997, Ruefenacht and Knight 1995, Wiegand and Schropfer 1997). These studies usually focused on narrow roadways and forest roads. In general, they found that while roads limited movement, the few individuals crossing the roads were probably sufficient to prevent substantial genetic divergence of the divided population. However, in one of the few studies to investigate the effects of divided multi-lane highways, Oxley et al. (1974) did not detect any crossings of small mammals through these wider roadway corridors. Reh and Seitz (1990) also found substantial evidence of genetic isolation caused by highways and railroads in common frog populations in southern Germany. It should also be noted that most of these studies address the impacts of single roads, while the barrier effects of roads are likely to be additive (the more roads between two populations, the lower the probability of movement between populations).

Direct Mortality

In addition to influencing roadway crossing behavior, direct road mortality may affect population dynamics for some species. Road mortality is also a concern because of its association with issues of human safety and animal welfare. Based on a survey of state wildlife and transportation agencies, Romin and Bissonette (1996) estimated that the national deer road-kill for 1991 totaled at least 500,000 deer. Banks (1979) estimated that annual mortality of birds in collisions on U.S. roads was 57.2 million individuals. Generally, direct mortality from vehicle collisions acts in a density-dependent manner. The species killed most often are those most common in roadside habitats (Geis 1981). The majority of these species are associated with the early successional and edge habitats characteristic of roadsides, and tend to be common across human altered landscapes. Due to the relatively large and well distributed populations of most of these species, the demographic effects of most road-related mortality are not considered to be substantial (Conover et al. 1995, Cook and Daggett 1995, Groot Bruinderink and Hazebroek 1996). However, there are important exceptions to this generality.

Wildlife populations that are most likely to be impacted by road related mortality are those that have patchy distributions (i.e., species associated with unique, discrete habitats) adjacent to busy highways, or low density species which, because of foraging or dispersal behaviors, regularly encounter roads in ways that increase their vulnerability to collisions. For example, Fowle (1996) documented differences in age structure and density related to distance from a busy highway for painted turtles occupying pothole wetlands in western Montana. Black bear and panther populations in Florida have been substantially influenced by mortality resulting from roadway crossing (Foster and Humphrey 1992, Gilbert and Wooding 1996). In Banff National Park, 83% of documented coyote deaths and 76% of wolf deaths were the result of collisions with vehicles (Gibeau and Heuer 1996, Paquet et al. 1996). Seventy-five to eighty percent of all mortality for the endangered Key Deer in Florida is the result of collisions with cars (Calvo and Silvey 1996). Road related mortality of badgers in northern Europe has been identified as a major cause of decline for that species (Aarissorensen 1995, Broekhuizen and Derckz 1996, Davis et al. 1987).

Cook and Daggett (1995) listed 18 endangered species that experience significant mortality from vehicle collisions. These species are desert tortoise in California, Nevada, and Utah; panther, black bear, and Key deer in Florida; timber rattlesnake, rat and coachwhip snakes, and chorus frogs in Illinois; spotted skunk and blackfooted ferret in Kansas; wolf in Michigan; bald eagle in Utah, Delaware and Maryland; river otter and wolverine in Colorado; Delmarva fox squirrel in Delaware and Maryland; and swift fox in South Dakota; tiger salamander and bog turtle in New York (Cook and Daggett 1995). Owls may be particularly vulnerable to road mortality due to their nocturnal behavior and association with roadside habitats for foraging (Loos and Kerlinger 1993; Moore and Mangel 1996; Nero 1981, 1986; Newton et al. 1991; Sutton 1996).

Road mortality can be catastrophic for species that have mass movements of entire breeding populations as is characteristic of some amphibians. Van Gelder (1973) documented 30% mortality for a population of common toad when they were migrating across a road to a breeding pond. This mortality rate occurred with a traffic load of 9.4 vehicles per hour and could be expected to be much higher with increased traffic volumes. Similar phenomena have been documented elsewhere (Ashley and Robinson 1996, Barry and Shaffer 1994, Cooke 1988, Jackson 1996, Kolodenko 1981). Road-related mortality may impact some insect populations as well (Beckemeyer 1996).

HIGHWAY SAFETY

Concerns about vehicle/animal collisions extend beyond the individual animals and populations to issues of human safety and property damage. A number of comprehensive reviews on this subject have been published recently (Conover et al. 1995, Cook and Daggett 1995, Groot Bruinderink and Hazebroek 1996, Putman 1997, Romin and Bissonette 1996). Cook and Daggett (1995) reported that 113 people were killed in animal/vehicle collisions in the U.S. in 1993. They estimate that the total cost of animal/vehicle collisions is about $1.2 billion a year. Conover et al. (1995) put the estimate of yearly animal/vehicle collisions in the U.S. at over 1 million, causing 29,000 human injuries and 211 fatalities. They estimate the total yearly vehicle repair costs to be $1.1 billion.

Vehicle/animal collisions are clearly an issue of substantial concern and the problem appears to be growing. Romin and Bissonette (1996) reported that deer road kills had increased between 1982 and 1991 in 26 of 29 states that had collected trend data. Cook and Daggett (1995) reported that most states had 30% to 50% increases in deer road kills over the past ten years.

Animal/vehicle collisions are not random events on the landscape. Gilbert and Wooding (1996) found that 30% of black bear road mortalities in Florida were concentrated in 12 problem areas. Carbaugh et al. (1975) point out that deer/vehicle collisions are a function of highway location relative to deer habitat requisites such as feeding and resting sites and the availability of feeding areas other than the road right-of-way. Puglisi et al. (1974) found that the most important factors influencing deer collision location were highway fencing and forage availability. The lowest deer kill rates were in areas where forage was available outside the fenced right-of-way. In areas with similar deer densities, roads in agricultural landscapes generally have lower deer/vehicle collision rates than those in forested areas (Carbaugh et al. 1975, Romin and Bissonette 1996).

Deer/vehicle collisions have also been correlated with vegetation (usually presence of brushy cover or forest adjacent to the right-of-way), topography (usually draws that funnel deer movements), and steep roadside embankments that prevent deer from moving off the roadway (Bellis and Graves 1971, Romin and Bissonette 1996).

Seasonal movements and behavior patterns can influence the frequency of collisions. Deer/vehicle collision rates are generally highest in spring and fall due to forage availability, hunting pressure, and reproductive behavior (Bellis and Graves 1971, Cook and Daggett 1995, Feldhammer et al. 1986, Groot Bruinderink and Hazebroek 1996, Puglisi et al. 1974). Collisions are most frequent during the evening and morning hours when visibility is poor and animals are most likely to be active.

MANAGING WILDLIFE / HIGHWAY INTERACTIONS

Two types of practices for managing wildlife and highway safety have been identified (Koehne 1991): 1) habitat manipulations or structures that keep wildlife off roadways, and 2) measures that increase driver awareness and ability to prevent an accident should wildlife enter the road. A number of useful literature reviews have been published on this subject (Cook and Daggett 1995, Foster and Humphrey 1995, Groot Bruinderink and Hazebroek 1996, Putman 1997).

Keeping Wildlife Off The Road

One of two broad approaches to managing wildlife presence on roads can be taken: 1) wildlife presence on the road can be discouraged or displaced through the use of reflectors, repellents, or vegetation management; or 2) exclude wildlife from a section of roadway with fencing (Groot Bruinderink and Hazebroek 1996). Selection of the approach should be based on the type of wildlife movement involved (migratory or foraging), severity of the collision problem, and the type of roadway (Putman 1997).

Reflectors, repellents, vegetation management: Techniques that deter, but do not prevent, animal presence on roadways include reflectors, chemical repellents, whistles, and vegetation management. These techniques are usually most appropriate for areas with transient animal movement (e.g. migration routes) where animals will not become conditioned to the deterrents. Because of their lower cost compared to fencing, these deterrent techniques are often suitable for areas with low collision rates (Putman 1997).

Deterrent techniques have had mixed success. Studies of deer reflectors have shown significant reductions in collision rates (Pafko and Kovach 1996, Schafer and Penland 1985, Schafer et al. 1985), no effect (Ford and Villa 1993, Welsh and Healy 1993, Zacks 1985, 1986), and habituation of deer to the reflectors after an initial period of effectiveness (Reeves and Anderson 1993, Ujvari et al. 1998). Chemical repellents may be effective in discouraging use of specific roadside attractants such as salt accumulations (Fraser and Hristienko 1982) or concentrated forage patches (Dietz and Tigner 1968). Research on commercial wildlife warning whistles has not conclusively shown they are effective (Muzzi and Bisset 1990, Romin and Dalton 1992).

Management of vegetation to discourage animal presence on roadways focuses on limiting the availability of plants that attract wildlife and removing roadside cover. Removal of right-of-way vegetation has been shown to be effective in reducing moose/train collisions in Norway (Jaren et al. 1991). Groot Bruinderink and Hazebroek (1996) suggest avoiding mast producing trees (e.g., oaks) and using non-palatable, preferably thorny, species for roadside planting.

Fencing: Fencing is the most common and effective technique to prevent animals, particularly ungulates, from entering roadways (Bellis and Graves 1971, Falk et al. 1978, Ludwig and Bremicker 1981). Collision rates can be reduced more than 90% in fenced highway segments (McDonald 1991, Ward 1982). Roadways often divide animal home and seasonal ranges, so provision of adequate passageways is an important component of any fencing installation. In analyzing a successful fencing/underpass system in Wyoming, Ward (1982) noted four major difficulties: 1) overcoming initial deer anxiety and reluctance to use underpasses, 2) extending the fence to a length great enough to prevent end-runs, 3) preventing deer from crossing cattle-guards on the ramps, 4) promptly repairing holes in the fence, and 5) building one-way gates at the proper distance from underpasses.

Location and length of fencing are important design considerations for wildlife fencing installations. If the fenced segment is not long enough, collisions may simply be displaced to the end of the fence (McDonald 1991). Traditional crossing and foraging areas need to be considered in fence design. Incentive for fence penetration will be reduced if the fence is constructed parallel to traditional movement routes (Miller et al. 1972). The fence also needs to be constructed and maintained to prevent animals from going through the fence and being trapped on the roadway (Feldhammer et al. 1986, Miller et al. 1972). The location of highway fencing relative to ungulate forage can substantially influence the effectiveness of the fence. Motivation to penetrate the fence will be reduced if forage is available outside of the fenced area, and will be further reduced if forage is limited within the fence. Vegetation management on both sides of the fence can contribute to improved effectiveness (Bellis and Graves 1971, Feldhammer et al. 1986).

Without opportunities to exit the roadway, animals can become trapped inside fence installations (Putman 1997). One-way gates that allow escape from fenced highway segments are important features of wildlife fencing installations (Miller 1991, Putman 1997, Ward 1982). Care in designing one-way gates is necessary because they tend to be easily damaged, can be permeable to medium-sized animals, and ungulates can learn how to open the gates from the outside.

Passage structures: Passage structures serve two major functions: 1) they improve highway safety by reducing the incentive for an animal to penetrate or go around the end of a fencing installation, and 2) they provide for safe animal movement and connectivity across roadways. Wildlife passages most commonly involve the installation of drift fences leading to culverts or bridges specifically designed for wildlife passage. These passage structures range in scale from small tunnels and culverts for amphibian movement, to large "ecological connector" overpasses that provide passage for all species from grizzly bears to arthropods (Jackson 1996, Leeson 1996, Zangger 1995).

Roadway crossing structures have been installed for black bear and panthers in Florida (Foster and Humphrey 1995, Gilbert and Wooding 1996, Land and Lotz 1996, Roof and Wooding 1996), badgers in Europe (Broekhuizen and Derckx 1996), mountain goats in Montana (Pedevillano and Wright 1987), deer in Wyoming (Ward 1980), and a variety of carnivore and herbivore species in Alberta (Clevenger 1997, Leeson 1996). Small-scale underpasses for amphibian movement have been successfully installed in Europe (Engel and Bressanutti 1993) and the United States (Jackson 1996). Similar passages have been installed for tortoise in France (Guyot and Clobert 1997). Boarman and Sazaki (1996) found

88% fewer small vertebrate carcasses and 93% fewer tortoise carcasses in a portion of highway with passage culverts and drift fencing designed for desert tortoises in the Mojave Desert.

Large-scale "ecological connector" overpasses have been proposed in Montana (Becker 1996), and constructed in Europe (Groot Bruinderink and Hazebroek 1996, Pfister and Keller 1995), New Jersey (Kuennen 1989), and Banff National Park, Alberta (Leeson 1996). These "ecological connector" structures are 50 to 100 meters wide and are designed to support natural vegetation over the entire width of the highway right-of-way. Analysis of the effectiveness of these structures in providing habitat connectivity for wildlife is not yet available in the published literature.

The success of wildlife passage installations is dependent on the design and location of the structure and how well they correspond to the behavioral characteristics of the target species. Gibeau and Heuer (1996) found that female grizzly bears did not make use of wildlife passage structures under highways in Banff National Park, Alberta. Paquet and Callahan (1996) found that wolf use of the same structures was highly variable by individual. Ward (1980) found that deer used crossing structures in Wyoming while antelope did not. Panther use of underpasses in Florida increased when they became accustomed to them (Land and Lotz 1996).

The location of the structure is critical to its success. Land and Lotz (1996) suggested that the effectiveness of structures providing panther crossing was more dependent on the location of the structure in relation to traditional movement routes than on the design of the structure. Analysis of animal movement patterns through habitat evaluations, radio-telemetry, tracking studies, and identification of animal/vehicle collision concentration areas are methods of identifying appropriate crossing structure locations (Groot Bruinderink and Hazebroek 1996, Putman 1997).

The "openness" of the structure also is important relative to the variety of species that may be expected to use the structure. Olbrich (1984, cited in Putman 1997) calculated "openness" by the (height x width)/length. Based on a review of wildlife underpasses in Europe, he suggested that red deer and fallow deer did not use underpasses where this ratio was less than 1.5, and roe deer did not use underpasses with a ratio of less than 0.75. Reed (1981) found that about 75% of mule deer entering a 10x10x100-foot box culvert (openness ratio of 1) were stressed. In addition to openness, other crossing structure features that may improve the likelihood of animal passage include the presence of a natural or dirt substrate floor, natural vegetation within the structure, light colored walls, and the absence of artificial lighting (Putman 1997, Woelfel and Kruger 1995).

In some instances, wildlife will use existing structures, such as culverts and bridges, to move safely through roadway corridors (Rodriguez et al. 1996, Yanes 1995). LeBlanc (1994) found weasel, squirrel, coyote, marten, and elk using structures not designed for wildlife passages beneath the Trans-Canada highway in Banff National Park. The most important factors influencing the use of these structures were the presence of forest cover near the entrance and the depth of the entrance below the highway surface. In some situations, slight modifications to existing structures (e.g., providing pathways along streambanks under existing bridges) can provide effective animal passage (LeBlanc 1994).

Increasing Driver Awareness and Ability to Avoid Collisions

Koehne (1991) suggests a number of methods to improve driver ability to prevent an accident should they encounter wildlife: 1) reduce vehicle speeds, 2) increase vegetation clearance, 3) increase lighting, and 4) improve traction in slippery conditions. Bashore (1985) found that lower speed limits reduced the probability that a highway segment had a high deer/vehicle collision rate. Vegetation removal can be effective in reducing collisions (Jaren et al. 1991). Highway lighting did not reduce deer/vehicle collisions in Colorado (Colorado Division of Wildlife 1980, Reed and Woodard 1981). The role of highway traction in avoiding animal/vehicle collisions has not been evaluated in the published literature.

The most common technique in management of vehicle/animal collisions is the placement of warning signs. Reports of research on the effectiveness of warning signs are mixed. Borton (1984) found that warning signs significantly reduced collision rates. Aberg (1981) found that the presence of crossing signs increased detection of moose dummies along the road only for drivers without passengers. Pojar et al. (1975) found that collision rates were not affected by a crossing sign. Educational programs to improve driver awareness of wildlife hazards have also been suggested (Del Frate and Spraker 1991, Groot Bruinderink and Hazebroek 1996, Koehne 1991, Scanlon and Susan 1980).

Combination Measures

Construction and maintenance of wildlife fencing/passage installations is expensive. Reed et al. (1982) estimated that construction of wildlife fencing with underpasses was economically justified in areas with 24 or more deer/vehicle collisions per mile each year. This evaluation only considered the costs of deer/vehicle collisions. Another consideration is the role of passage structures in maintaining habitat and population connectivity, which can be of equal or greater importance, depending on the management objectives of the passage installation. He suggests that in areas with fewer collisions, less intensive methods may be appropriate. Wildlife fencing systems that funnel deer into clearly marked crosswalk areas (complete with visual queues painted on the road surface to encourage directional movement and automated warning signs) have been installed in northeastern Utah (Lehnert et al. 1996). These systems have had mixed success, but they do represent a creative combination of traditional techniques. For roads that have lighter traffic volumes, where the intention is to delay crossing rather than prevent it, a combination of warning signs, vegetation management, reduced speed limits, and reflectors is perhaps the best option currently available (Groot Bruinderink and Hazebroek 1996, Putman 1997).

SUMMARY AND CONCLUSIONS

Roads and highways are dominant features in the modern landscape. The interaction of roadways with wildlife poses significant threats to long-term biological diversity and costs more than a billion dollars and hundreds of lives each year in the United States alone. Roads influence wildlife by changing habitat quantity and quality, and altering animal movement patterns and distributions. Roads can be conduits for movement and range expansion for generalist and early successional associated species, but often these species are common, exotic, or undesirable. Road-associated disturbances and contaminants can degrade habitat quality. Direct mortality from vehicle collisions has substantial impacts on wildlife populations, particularly for species that have patchy distributions in habitats adjacent to busy highways, or low density species which regularly cross roadways or are attracted to roadside habitats in ways that increase their vulnerability to collisions. As barriers to animal movement, roads can lower population viability of habitat specialists and species sensitive to human disturbance by dividing larger populations into smaller groups more at risk of extinction and genetic change.

Management of highway and wildlife interactions often focuses on reducing animal/vehicle collisions and providing safe animal passage across the roadway corridor. Three broad approaches are usually taken: 1) keeping animals off the roadway, 2) increasing driver ability to prevent collisions, and 3) improving driver awareness of the dangers imposed by wildlife. Fencing and passage systems are commonly used to keep animals off the roadway and maintain habitat or population connectivity. Important considerations in the implementation of fencing and passage systems include: 1) the extent of the area to be fenced; 2) the alignment of the fence to reduce incentives to penetrate; 3) identification of appropriate crossing structure locations through analysis of animal/vehicle collision locations, animal movement studies, and habitat analysis; and 4) providing crossing structures of suitable design to encourage use by the target species.

Effective fencing and passage installations are expensive to construct and maintain. The cost of these installations limits their use to areas with substantial safety or ecological connectivity concerns. In areas with moderate collision rates and where species direct road mortality or population fragmentation is not a concern, other measures such as a combination of deer reflectors, warning signs, reduced speed limits, and vegetation management may be appropriate. In any situation, driver education regarding the safety and conservation implications of animal/vehicle collisions is crucial to the long-term success of managing wildlife and roadway interactions.

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Vermeulen, H. J. W. 1994. Corridor function of a road verge for dispersal of stenotopic heathland ground beetles (*Carabidae*). Biological Conservation. 69: 339-349.

Ward, A. L. 1980. Effects of highway operation practices and facilities on elk, mule deer and pronghorn antelope. Fort Collins, CO: Rocky Mountain Forest and Range Experiment Station.

Ward, A. L.; Fornwalt, S. E.; Henry, S. E.; Hodorff, R. A. 1980. Effects of highway operation practices and facilities on elk, mule deer, and pronghorn antelope. Washington, DC: U.S. Department of Transportation, Federal Highway Administration; FHWA-RD-79-143. 48 p.

Ward, A. L. 1982. Mule deer behavior in relation to fencing and underpasses on Interstate 80 in Wyoming. Transportation Research Record. 859: 8-13.

Warner, R. E. 1992. Nest ecology of grassland passerines on road rights-of-way in central Illinois. Biological Conservation. 59: 1-7.

Warner, Richard E.; Larry, M. D.; Stanley, L. E.; Joselyn, G. B. 1992. Costs and benefits of roadside management for ring-necked pheasants in Illinois. Wildlife Society Bulletin . 20(3): 279-285.

Way, J. M. 1970. Roads and the conservation of wildlife. Journal of the Institute of Highway Engineers. July: 5-11.

Way, J. M. 1977. Roadside verges and conservation in Britian: a review. Biological Conservation. 12: 65-74.

Welsh, C. J. E.; Healy, W. M. 1993. Ineffectiveness of Swareflex reflectors at reducing deer-vehicle collisions. Wildlife Society Bulletin. 21: 127-132.

Wiegand, P.; Schropfer, R. 1997. DNA fingerprinting analysis of subpopulations of the red squirrel (*Sciurus vulgaris*, l 1758). Journal of Zoological Systematics and Evolutionary Research. 35(2): 71-74.

Wilcox, Douglas A. 1989. Migration and control of purple loosestrife (*Lythrum salicaria* l.) along highway corridors. Environmental Management. 13(3): 365-370.

Woelfel, H.; Krueger, H. H. 1995. On the design of game passages across highways. Zeitschrift fuer Jagdwissenschaft. 41: 209-216.

Wolff, J. O.; Schauber, E. M.; Edge, W. D. 1996. Can dispersal barriers really be used to depict emigrating small mammals? Canadian Journal of Zoology. 74: 1826-1830.

Woods, J.; Munro, R. H. 1996. Roads, rails and the environment: wildlife at the intersection in Canada's western mountains. In: Evink, G.; Ziegler, D.; Garrett, P.; Berry, J., eds. Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors: Proceedings of the Florida Department of Transportation/Federal Highway Administration transportation-related wildlife mortality seminar; 1996 April 30-May 2; Orlando, FL. FHWA-PD-96-041. Washington, DC: U.S. Department of Transportation, Federal Highway Administration: 39-45.

Woodward, S. M. 1990. Population density and home range characteristics of woodchucks (*Marmota monax*) at expressway interchanges. Canadian Field Naturalist. 104(3): 421-428.

Yanes, M.; Suarez, F. 1995. Vertebrate crossing through culverts and under roads and railways. QUERCUS. 12: 31-33.

Ylaranta, T. 1995. Effect of road traffic on heavy metal concentrations of plants. Agricultural Science in Finland. 4(1): 35-48.

Zacks, J. L. 1985. An investigation of Swareflex wildlife warning reflectors, final report. Washington, DC: U.S. Department of Transportation, Federal Highway Administration; FHWA-MI-RD-85-04. 53 p.

Zacks, J. L. 1986. Do white-tailed deer avoid red? An evaluation of the premise underlying the design of Swareflex wildlife reflectors. Washington, DC: Transportation Research Board, National Research Council; Transportation Research Record 1075. 43 p.

Zangger, A. 1995. Wildlife overpasses over a motorway as connecting means for forest arthropod communities. Switzerland: Universitat Bern. 95 p. M.S. thesis.

Zelenak, J. R.; Rotella, J. J. 1997. Nest success and productivity of ferruginous hawks in northern Montana. Canadian Journal of Zoology. 75(7): 1035-1041.

Appendix A

Aarissorenson, J. 1995. Road-kills of badgers (*Meles meles*) in Denmark. Annales Zoologici Fennici. 32(1): 31-36.
The first major survey of road-killed animals in Denmark, conducted in 1991, showed that more than 3,600 badgers, *Meles meles*, equal to 10 to 15% of the total population, had been killed. Most badgers were killed during the summer when traffic intensity was highest. The traffic victims were very unevenly distributed across the country. This is not explained by differences in local traffic intensities alone, but also by differences in population density of the badger and the surroundings of the roads. Almost all road-killed badgers in 1992 and 1993 were adult, and female badgers were killed most frequently during spring whereas male badgers were killed throughout the year.

Aberg, L. 1981. The human factor in game-vehicle accidents: a study of driver's information acquisition. Uppsala, Sweden: Department of Psychology, Uppsala University. 130 p. Ph.D. thesis.
This is a psychology Ph.D. dissertation. He looked at visual search strategies while driving. He conducted two surveys regarding accidents and near accidents with moose, a study of detection of moose dummies along roadways, and a study of the effectiveness of game crossing signs. Presence of crossing signs increased detection of moose dummies along the road only for drivers without passengers.

Adam, M. D.; Lacki, M. J. 1993. Factors affecting amphibian use of road-rut ponds in Daniel Boone National Forest. Transactions of the Kentucky Academy of Science. 54(1-2): 13-16.

Adams, L. W.; Geis, A. D. 1978. Effects of highways on wildlife populations and habitats: selection and evaluation of procedures. Washington, DC: U.S. Department of Transportation, Federal Highway Administration; FHWA-RD-78-92. 179 p.
The work summarizes Phase I of a two-part investigation on the effects of highways on wildlife populations and habitats. Phase I was undertaken to select, test, and evaluate techniques and procedures for rapid and efficient assessment of wildlife populations and habitats in relation to roads and highways in the Pacific Northwest, the Midwest Tillplain, and the Southern Piedmont areas of the United States. Specific recommendations are made concerning cluster configuration for sampling units, and habitat, bird, mammal, amphibian, reptile, and wildlife road mortality surveys for Phase II of the study. In addition, detailed field procedures selected for the second phase of the study are presented.

Adams, L. W.; Geis, A. D. 1981. Effects of highways on wildlife. Washington, DC: U.S. Department of Transportation, Federal Highway Administration; FHWA/RD-81/067. 152 p.
Effects of highways on the diversity and spatial distribution of wildlife were studied in the southern Piedmont of Virginia, North Carolina, and South Carolina; the Midwest Tillplain of Illinois; the valley region of Oregon between the Cascade and Coastal ranges; and the central portion of northern California. Sample plots were distributed in relation to interstate highways and county roads and extended perpendicularly from roadside edges to 400 m from each road type. Nine bird species were positively influenced and nine species negatively influenced by one or both road types during either the breeding or winter season. Small mammal community structure and abundance were influenced by roads. Grassland species generally preferred right-of-way (ROW) habitat and many less-habitat-specific species were distributed in ROW and adjacent habitat. Seventy-six percent of the road wildlife mortality was on interstate highways.

Adams, L. W.; Geis, A. D. 1981. Roads and roadside habitat in relation to small mammal distribution and abundance. In: Tillman, R. E., ed. Proceedings of second symposium on environmental concerns in rights-of-way management; 1979 October 16-18; Ann Arbor, MI. Ann Arbor: University of Michigan: 1-54.

Adams, L. W.; Geis, A. D. 1983. Effects of roads on small mammals. Journal of Applied Ecology. 20: 403-416.
They found that small mammal density and diversity were greater in interstate right-of-ways than in

adjacent habitats for study areas in the South, Midwest, California, and Oregon. They suggest that right-of-way habitat and its accompanying edge are attractive not only to grassland species, but also to many less habitat-specific species that make use of the adjacent edge habitat. They documented mortality by species and state that it did not appear to be detrimental to populations, but they do not give mortality relative to population density.

Adams, L. W. 1984. Small mammal use of an interstate highway median strip. Journal of Applied Ecology. 21: 175-178.

Adams, L. W.; Geis, A. D. 1984. Effects of roads on breeding birds. In: Crabtree, A. F., ed. Proceedings of the third international symposium on environmental concerns in rights-of-way management; 1982 February 15-18; San Diego, CA. [Locations of publisher unknown]: Mississippi State College: 562-569.

Adams, L. W.; Dove, L. E. 1989. Wildlife reserves and corridors in the urban environment: a guide to ecological landscape planning and resource conservation. Columbia, MD: National Institute for Urban Wildlife. 91 p.

Ager, A.; Hitchcock, M. 1994. Heicalc - elk habitat-effectiveness index software. Wildlife Society Bulletin. 22(1): 126-128.

Albasel, N.; Cottenie, A. 1985. Heavy metal contamination near major highways, industrial and urban areas in Belgian grassland. Water, Air, Soil Pollution. 24: 103-109.

Allen, R.; McCullough, A. 1976. Deer-car accidents in southern Michigan. Journal of Wildlife Management. 40(2): 317-325.

Allen, S. H.; Sargeant, A. B. 1993. Dispersal patterns of red foxes relative to population density. Journal of Wildlife Management. 57: 526-533.
Factors affecting red fox (*Vulpes vulpes*) dispersal patterns are poorly understood but warranted investigation because of the role of dispersal in rebuilding depleted populations and transmission of diseases. We examined dispersal patterns of red foxes in North Dakota (USA) based on recoveries of 363 of 854 foxes tagged as pups and relative to fox density. Foxes were recovered up to 8.6 years after tagging; 79% were trapped or shot. Straight-line distances between tagging and recovery locations ranged from 0 to 302 km. Mean recovery distances increased with age and were greater for males than females, but longest individual recovery distances were by females. Dispersal distances were not related to population density for males ($P = 0.36$) or females ($P = 0.96$). The proportion of males recovered that dispersed was inversely related to population density ($r = -0.94$; $n = 5$; $P = 0.02$), but not the proportion of females ($r = -0.49$; $n = 5$; $P = 0.40$). Dispersal directions were not uniform for either males ($P = 0.003$) or females ($P = 0.006$); littermates tended to disperse in similar directions ($P = 0.09$). A 4-lane interstate highway altered dispersal directions ($P = 0.001$). Dispersal is a strong innate behavior of red foxes (especially males) that results in many individuals of both sexes traveling far from natal areas. Because dispersal distance was unaffected by fox density, populations can be rebuilt and diseases transmitted long distances regardless of fox abundance.

Alvarez, B. I.; Frean, H. 1992. Vertebrates run over on two roads in Ourense. First report. In: Lopez, Redondo, ed. I jornadas para el estudio y prevencion de la mortalidad de vertebrados en carreteras, Madrid, 5 y 6 de Octubre de 1991. Tomo 2. [Sessions in the study of prevention of road mortalities of vertebrates, Madrid, 5 and 6 October, 1991. Volume 2.]. Ambiental, Madrid: Coordinadora de Organizacciones de Defensa: 239-251.

Amor, R. L.; Stevens, P. L. 1976. Spread of weeds from a roadside into sclerophyll forests at Dartmouth, Australia. Weed Research. 16: 111-118.

Andersen, R.; Wiseth, B.; Pedersen, P.; Jaren, V. 1991. Moose-train collisions: effects of environmental conditions. Alces. 27: 79-84.
The effects of environmental conditions during winter (1 November-14 April) on moose-train collisions was investigated along a 92.2 kilometer long section of the Nordlandsbanen railway, in Norway between 1980 and 1988. The total number of train kills was 262, and ranged between 71 (1983/84) and 8 (1984/85) kills per year. Mean winter snow depth explained 84% of the annual variation. A high proportion of moose were killed when snow depth exceeded 100 cm. High ambient temperatures reduced the risk of collisions, while low temperatures had the opposite effect. Fifty four percent of all moose were killed shortly after a snowfall, however the mechanisms involved are still unknown. It is recommended that train speed be reduced through high risk sections of the railway, especially in periods with high snow frequency, high snow depth and low ambient temperatures.

Anderson, R. C. 1979. The value of roadside verges to wildlife. Tigerpaper. 6(4): 15-16.

Andreassen, H. P.; Ims, R. A.; Steinset, O. 1996. Discontinuous habitat corridors - effects on male root vole movements. Journal of Applied Ecology. 33(3): 555-560.
1. We tested how movement rates of male root voles were affected by discontinuities (gaps) in a 1-m wide habitat corridor. 2. Gaps of increasing size (0.5-4 m) were created experimentally by mowing the vegetation. Movement rates (recorded by radiotelemetry) were compared between the manipulated corridor and a contemporal, unmanipulated (continuous) control corridor. 3. Male root voles did not respond to gaps until the gap size became 4 m which is equivalent to approximate to 10-20% of the normal home range diameter. Gap sizes of 4 m in the corridor decreased the movement rates significantly and to the same degree for two behaviorally distinct strains of root voles. 4. The similar responses of the two vole strains indicated that the results may have validity beyond the particular experimental setting employed.

Andren, H. 1994. Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review. Oikos. 71(3): 355-365.
They combine ideas from landscape ecology with classical aspects of communities in habitat islands to try to identify the factors influencing the abundance and distribution of species in landscapes with different degrees of habitat fragmentation. Using artificially generated maps, they found that landscapes broke down into separate patches when the amount of original habitat reached 60%, and patches became isolated at <40%. Patterns of grain dispersal will influence these thresholds. They compare these predictions to existing literature.

Andrews, A. 1990. Fragmentation of habitat by roads and utility corridors: a review. Australian Zoologist. 26(3-4): 130-141.
This review examines the ecological effects of roads and utility corridors such as powerlines, pipelines, canals and railway lines on undisturbed habitat and native wildlife. Public concern about roads in natural areas is increasing, as shown by the public protests against forest roads in the Central Highland of Victoria and the National Estate areas in the south-east forests of New South Wales. The Daintree Road through Queensland's tropical rainforest created an international protest and remains Australia's most notorious road. The original Very Fast Train (VFT) proposal favored a route which would have divided the two major wilderness areas of the Gippsland forest in Victoria by creating a fenced impenetrable barrier to some wildlife. Planning authorities need to address the impacts of fragmentation of natural habitats by such developments. Although it is difficult to draw conclusions from a comparison of studies covering different countries, species and habitats, areas of concern for wildlife conservation and management emerge, including increased mortality, divided populations and invasions of common species. There is need for studies on the effects of these linear artifacts on Australian wildlife.

Angold, P. G. 1997. The impact of a road upon adjacent heathland vegetation - effects on plant species composition. Journal of Applied Ecology. 34(2): 409-417.
The effect of a road upon heathland vegetation was investigated at five sites adjacent to the main trunk

road through the New Forest, Hampshire, UK, with nine supplementary sites adjacent to five minor roads. There was enhanced growth of vascular plants, notably heather and grass species near the road, which was probably due to oxides of nitrogen from vehicle exhausts. There was a decrease in the abundance and health of lichens near the road. There was an increase in the abundance of grasses in the heathland near roads, which may be due to the changes in relative competitive ability of plant species under conditions of eutrophication. The extent of the edge effect in the heath was closely correlated with the amount of traffic carried by the road, with a maximum edge effect of 200 meters adjacent to a dual carriageway. This should be taken into account when considering the environmental impact of new roads. Road widening with its associated increase in traffic can also be expected to impact on existing oligotrophic communities beyond the actual land-take. Such schemes should include buffer zones to protect oligotrophic communities or other measures to minimize the pollution input from vehicle exhausts to environmentally sensitive areas.

Anon. 1982. Wildlife mortality in transportation corridors in Canada's National Parks. Natural Resource Bulletin.

Apps, C. 1997. Identification of grizzly bear linkage zones along the Highway 3 corridor of southeast British Columbia and southwest Alberta. Calgary, Alberta: Aspen Wildlife Research. 45 p.
An excellent application of Servheen and Sanstrom's grizzly LZP model for identification of bear linkage zones.

Archibald, W. R.; Ellis, R.; Hamilton, A. N. 1987. Responses of grizzly bears to logging truck traffic in the Kimsquit River Valley, British Columbia. International Conference on Bear Research and Management. 7: 251-257.
To assess the impacts of log truck traffic on grizzly bears (*Ursus arctos*) in Coastal British Columbia, the zone of hauling activity (zha) in the Kimsquit River study area was mapped using the sound levels (dB[C]) recorded at 25 meter intervals along 200 meter transects perpendicular to the road. The logging road bisected the home ranges of two adult female grizzly bears that were intensively monitored by radiotelemetry. There was a 78% reduction in the percentage of relocations in the zha between years not during and during hauling. Screening vegetation was not demonstrated to be a substantial factor influencing use of the zha because the entire zha was avoided during hauling. Road crossing intra-territorial movements were also reduced during hauling.

Armstrong, J. J. 1992. An evaluation of the effectiveness of Swareflex deer reflectors. Downsview, Ontario: Transportation Research Lab., Ontario Ministry of Transportation; 9303RT368E. 15 p.

Arnold, D. A. 1978. Characteristics and cost of highway deer kills. In: Kirkpatrick, C. M. , ed. The 1978 John S. Wright Forestry Conference. Lafayette, IN: Department of Forestry and Natural Resources and Indiana Cooperative Extension Service, Purdue University: 92-101.
The author analyzed the 63,184 deer vehicle collisions that occurred in Michigan from 1972 to 1976. Seventy percent of the collisions occurred after dark. Weather and human error were not factors in collision occurrence. Most collisions occurred on non-interstate rural roads. Collisions peaked in the fall, probably due to the rut and changing food availability. They found that there was a closer correlation between the number of accidents and traffic volume than between accidents and deer populations, though both relationships were significant. During the 5 years analyzed, 3446 people were injured and 17 killed. Total cost of collisions was estimated to be between 10 and 25 million dollars for the five year period. They suggest that underpasses are not suited to the dispersed movement patterns of white-tailed deer.

Arnold, D. A. 1979. Deer on the highway. Traffic Safety. May. [Pages unknown].

Arnold, G. W.; Algar, D.; Hobbs, R. J.; Atkins, L. 1987. A survey of vegetation and its relationship to vertebrate fauna present in winter on road verges in the Kellerberrin District, W.A. [Location of publication unknown]: Western Australia Department of Conservation; Land Manage. Tech. Rep. No. 18. 37 p.

Arnold, G. W.; Weeldenburg, J. R. 1990. Factors determining the number and species of birds in road verges in the wheatbelt of western Australia. Biological Conservation. 53(4): 295-315.

Arnold, G. W.; Weeldenburg, J. R.; Steven, D. E. 1991. Distribution and abundance of two species of kangaroo in remnants of native vegetation in the central wheatbelt of western Australia and the role of native vegetation along road verges and fencelines as linkages. In: Saunders, D. A.; Hobbs, R. J., eds. Nature conservation 2: the role of corridors. Chipping Norton, Australia: Surrety Beatty and Sons: 273-280.

Ashley, E. P.; Robinson, J. T. 1996. Road mortality of amphibians, reptiles, and other wildlife on the Long Point Causeway, Lake Erie, Ontario. Canadian Field Naturalist. 110: 403-412.
Wildlife road mortality on a 3.6 kilometer section of a two-lane paved causeway adjacent to Big Creek National Wildlife Area on Lake Erie was censured from spring to autumn for two 2-year periods, 1979 to 1980 and 1992 to 1993. Total recorded mortality exceeded 32,000 individuals, the majority being young of the year Leopard frogs. One hundred vertebrate species were recorded, 7 amphibians (n = 30,034), 10 reptiles (n = 864), 21 mammals (n = 282) and 62 birds (n = 1,302). Amphibian (leopard frog, bullfrog, green frog, American toad) and reptile (painted turtle, snapping turtle, Blanding's turtle and garter snake) mortality showed seasonal patterns consistent with life history phenology. Amphibian mortality was significantly associated with adjacent roadside vegetation and turtle road mortality with adjacent open water areas (P # 0.05). Factors that influence herpetofaunal road mortality and management options for reducing mortality on the causeway are discussed.

Askins, R. A. 1994. Open corridors in a heavily forested landscape: impact on shrubland and forest-interior birds. Wildlife Society Bulletin. 22: 339-347.

Auerbach, N.; Walker, M. D.; Walker, D. A. 1997. Effects of roadside disturbance on substrate and vegetation properties in arctic tundra. Ecological Applications. 7: 218-235.

Ault, J. W., III. 1982. Quantitative estimate of barn owl nesting habitat quality. [Location of publisher unknown]. Oklahoma Cooperative Wildlife Research Unit. 40 p. M.S. thesis.

Aye, P. P.; Nakamura, R. M.; Sawa, T. R.; Silva, P. 1995. Mortality of owls in Hawaii. Elepaio. 5(2): 9-12.

Ayeni, A. O.; Lordbanjou, D. T.; Majek, B. A. 1997. *Tithonia diversifolia* (Mexican sunflower) in south-western Nigeria - occurrence and growth habit. Weed Research. 37(6): 443-449.
A reconnaissance survey of the occurrence of *Tithonia diversifolia* (Hemsl.) A. Gray in southwestern Nigeria was carried out along the major highways linking Ibadan to major towns between April and August in 1991 and 1992. The survey revealed that *T. diversifolia* is prominent along the Ibadan-Oyo-Ogbomosho-Ilorin, Ibadan-Abeokuta and Oyo-Iseyin-Saki roads, and common along the Ibadan-Iwo-Osogbo-Offa, Ibadan-Ife-Akure, Ife-Ondo and Ibadan-Ijebu Ode roads. It is rare along Ibadan-Ikeja, Akure-Ado Ekiti-Kabba, Ilorin-Jebba, and Ijebu Ode-Benin City-Asaba roads. *Tithonia diversifolia* is a shallow-rooted annual/perennial broad-leaved plant that grows to a height of 5 m or more and varies from highly branched at low populations (<5 plants/m^2) to practically unbranched at high populations (>30 plants/m^2). Under natural conditions in the Ibadan area (7 degrees 25'N, 3 degrees 54'E), *T. diversifolia* is established from seed in March-April, flowers between September and November and produces mature seed by December-January. Seed is disseminated between January and March by shedding. Under frequent slashing or in a valley bottom with a high water table, or on river banks *T. diversifolia* behaves as a perennial shrub and flowering under this condition occurs sporadically throughout the year. [References: 5]

Ayres, J. Marcio; de Magalhaes Lima, Deborah; de Souza Martins, Eduardo; Barrrios, Jose Luis. 1991. On the track of the road: changes in subsistence hunting in a Brazilian Amazonian village. In: Robinson, J. T.; Redford, K. H., eds. Neotropical wildlife use and conservation. Chicago: University of Chicago Press: 82-92.

Babiloni, Gonzalez G. 1992. Provisional report of the mortality of vertebrates on the roads of Barcelona Province, September 1991. In: Lopez, Redondo, ed. I jornadas para el estudio y prevencion de la mortalidad de vertebrados en carreteras, Madrid, 5 y 6 de Octubre de 1991. Tomo 2. [Sessions in the study of prevention of road mortalities of vertebrates, Madrid, 5 and 6 October, 1991. Volume 2.]. Ambiental, Madrid: Coordinadora de Organizacciones de Defensa: [Pages unknown].:

Bahillo, Martin M.; Orizaola, Pereda G. 1992. Provisional report of the mortality of vertebrates on the roads of Cantabria, September 1991. In: Lopez, Redondo, ed. I jornadas para el estudio y prevencion de la mortalidad de vertebrados en carreteras, Madrid, 5 y 6 de Octubre de 1991. Tomo 2. [Sessions in the study of prevention of road mortalities of vertebrates, Madrid, 5 and 6 October, 1991. Volume 2.]. Ambiental, Madrid: Coordinadora de Organizacciones de Defensa: [Pages unknown].:

Baker, T. 1996. Habitat: a landscape architecture perspective. In: Evink, G.; Ziegler, D.; Garrett, P.; Berry, J., eds. Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors: Proceedings of the Florida Department of Transportation/Federal Highway Administration transportation-related wildlife mortality seminar; 1996 April 30-May 2; Orlando, FL. FHWA-PD-96-041. Washington, DC: U.S. Department of Transportation, Federal Highway Administration: 228-234.
This paper describes some greenway projects in Dade County, Florida.

Bakowski, C.; Kozakiewicz, M. 1988. The effect of forest roads on bank vole and yellow-necked mouse populations. Acta Theriologica. 33(25): 345-353.
Movements of bank voles (*Clethrionomys glareolus*) and yellow-necked mice (*Apodemus flavicollis*) across forest roads were studied. Bank vole populations on both sides of the road were characterized and returns of individuals of this species, experimentally translocated to the other side of the road and into the forest, were analyzed. It was found that the road did not restrict or limit the movement of mice, but it did so in the case of voles. The animals which had been translocated into the forest returned to the previous place quicker and in greater numbers than those translocated to the other side of the road.

Ballasina, D. 1989. Toads on roads in Belgium. In: Langton, T. E. S., ed. Amphibians and roads. Proceedings of the toad tunnel conference; 1989 January 7-8; Rendsburg, Federal Republic of Germany. Shefford, England: ACO Polymer Products Ltd.: 83-86.

Ballon, P. 1980. Problemes poses par les grandes infrastructures lineaires vis-a-vis des populations de grands animaux. CiconiA.(1): 69-83.

Ballon, P. 1985. Statement on preparatory techniques undertaken in France to reduce the impact of highway construction on game ungulates. Transactions of the Congress of the International Union of Game Biologists. 17: 679-689.

Banks, R. C. 1979. Human related mortality of birds in the United States. Washington D.C.: U.S. Department of the Interior, Fish and Wildlife Service; Special Scientific Report - Wildlife No. 215. 16 p.
Hunting was the largest direct mortality factor and accounted for about 61% of human related bird deaths. Control or prevention of avian depredations took about 1% of the total, and all research and propagation about 0.5%. Collision with man-made objects was the greatest indirect human cause of avian deaths, accounting for about 32% of the human related deaths. Pollution and poisoning caused the death of about 2% of the total. A relatively few species account for most of this mortality but continue to maintain large, harvestable populations, suggesting that the numbers of most bird species are essentially unaffected by the human activities discussed. Other activities of man that do not necessarily result in the death of birds but reduce reproductive potential are more likely to have long-term effects on avian populations.

Banks, W. A.; Adams, C. T.; Lofgren, C. S. 1990. Damage to North Carolina and Florida highways by red imported fire ants (*Hymenoptera*: Formicidae). Florida Entomologist. 3(1): 198-199.

Barnes, R. F. W.; BARNES, K. L.; Alers, M. P. T.; Blom, A. 1991. Man determines the distribution of elephants in the rain forests of northeastern Gabon. African Journal of Ecology. 29(1): 54-63.
Dropping counts were used to assess elephant abundance in the remote forests of northeastern Gabon where there are few people and no logging. Elephants prefer the secondary forest which grows on abandoned villages and plantations, but avoid roads and villages. Thus elephant distribution is governed by the distribution of both past and present human settlement, even in the remotest and least disturbed forests of equatorial Africa.

Barnett, J. L.; How, R. A.; Humphreys, W. F. 1978. The use of habitat components by small mammals in eastern Australia. Australian Journal of Ecology. 3: 277-285.
Overgrown tracks <8 meter wide inhibited movements of the brown antechinus (*Antechinus stuartii*).

Barragan, F. 1992. Provisional report of the mortality of vertebrates on the roads of Asturias, September 1991. In: Lopez, Redondo, ed. I jornadas para el estudio y prevencion de la mortalidad de vertebrados en carreteras, Madrid, 5 y 6 de Octubre de 1991. Tomo 2. [Sessions in the study of prevention of road mortalities of vertebrates, Madrid, 5 and 6 October, 1991. Volume 2.]. Ambiental, Madrid: Coordinadora de Organizacciones de Defensa: 101-109.

Barrett, D. E. 1996. Traffic-noise impact study for least Bell's vireo habitat along California State Route 83. Transportation Research Record. 1559: 3-7.
A traffic-noise study was conducted to determine the impact that a highway reconstruction project would have on a habitat area for the least Bell's vireo, a federally protected songbird. Federal Highway Administration and California Department of Transportation policies do not address the impact of noise on wildlife species; the study was conducted in response to a requirement of the U.S. Fish and Wildlife Service. Several mitigation measures were considered, including approximately 1200 meter (4,000 ft.) of temporary noise barriers. The outcome of the study was to provide funds for in-kind mitigation through habitat restoration rather than direct mitigation of noise impacts. This study contributes to a growing precedent of considering noise mitigation specifically for the protection of wildlife and raises several policy issues. Despite the increasing number of noise-mitigation projects for endangered birds and the commitment of significant funds to these undertakings, there remains a lack of firmly based noise-impact criteria and guidelines for noise mitigation.

Barry, S. J.; Shaffer, H. B. 1994. The status of the California tiger salamander (*Ambystoma californiense*) at Lagunita: a 50-year update. Journal of Herpetology. 28: 159-164.
We review the history of the California tiger salamander (*Ambystoma californiense*) population at Lagunita, a 114-year old reservoir at Stanford University, Santa Clara County, California. The animals apparently colonized the reservoir during the late 19th century, reached a population peak during the first half of the 20th century, and have declined since to near extinction. The apparent causes of this decline are habitat loss due to urbanization, adult salamander mortality from automobiles, loss of larvae during the annual reservoir drainage, and possibly predation by transient fish populations. Recommendations to preserve the population and to allow its size to increase include 1) construction of a drift fence and tunnel system to divert migrating adults and juveniles underneath the highway, 2) maintenance of water levels through mid-summer to allow most larvae to complete metamorphosis, and 3) excavation of sumps in the lake bed to entrap larvae and keep them from being swept down the lake drain.

Bart, J.; Hofschen, M.; Peterjohn, B. G. 1995. Reliability of the breeding bird survey - effects of restricting surveys to roads. Auk. 112(3): 758-761.

Bascompte, J.; Sole, R. 1996. Habitat fragmentation and extinction thresholds in spatially explicit models. Journal of Animal Ecology. 65: 465-473.
The incidence of habitat destruction on the survivorship of a single metapopulation is studied by means of a spatially explicit model. As the proportion of destroyed sites increases, the structural properties of the resulting landscape change in a non-linear way, showing the existence of critical

thresholds and phase transitions. Such critical thresholds are identified by means of an order parameter, which discriminates a quantitative process, i.e. habitat loss, from a qualitative one, i.e. habitat fragmentation. This difference is only well understood using a spatially explicit framework. We introduce on such a fragmented landscape the dynamics of a metapopulation balanced by local colonization and extinction by means of the cellular automaton formalism. The existence of extinction thresholds when a given fraction of habitat is destroyed is reported. These thresholds are determined both by the critical behavior of the landscape structural properties, and by the demographic properties of the metapopulation. Some differences between these results and those derived from the study of spatially implicit models are described and explained. In particular, the percentage of patch occupancy is lower for a given value of habitat destruction in the spatially explicit formulation. Extinction threshold also take place for a lower destruction value. Some implications for the management of natural landscapes are discussed.

Bashore, T. L.; Bellis, E. D. 1982. Deer on Pennsylvania airfields: problems and means of control. Wildlife Society Bulletin. 10: 386-388.

Bashore, T. L.; Tzilkowski, W. M.; Bellis, E. D. 1985. Analysis of deer-vehicle collision sites in Pennsylvania. Journal of Wildlife Management. 49(3): 769-774.
Nineteen habitat and highway characteristics thought to influence numbers of white-tailed deer vehicle collisions along Pennsylvania two-lane highways were tested for inclusion in a model used to predict probabilities of sections of highways being high deer kill sites. Two variables (in-line visibility and non-wooded) increased the probability of a section of highway being a high kill site. Seven variables (residences, commercial buildings, other buildings, shortest visibility, speed limit, distance to woodland, and fencing) decreased this probability. Removal of the variables speed limit and other buildings did not significantly change the model. The model showed strong discrimination between high kill and low kill (control) sections of highway.

Basile, J. V.; Lonner, T. N. 1979. Vehicle restrictions influence elk and hunter distribution in Montana. Journal of Forestry. 77: 155-159.

Baur, A.; Baur, B. 1990. Are roads barriers to dispersal in the land snail (*Arianta arbustorum*)? Canadian Journal of Zoology. 68: 613-617.
The effect of road width on dispersal in the land snail (*Arianta arbustorum*) was examined by recording displacements of marked individuals during one activity season (three months) in central Sweden. For two sites, a paved road (8 meter side, low traffic density) and an unpaved track (3 meter wide), the snails' movements were largely confined to roadside verges. The snails followed the vegetation belts; the average displacements ranged from 1.5 to 4.9 meters at different sites. Several snails covered large distances, the maximum recorded being 14 meters. Despite these long-distance dispersers, only one of the recaptured snails crossed the paved road and two crossed the track, indicating that the road and to a minor extent, the track acted as dispersal barriers. By contrast, an overgrown path (0.3 meter wide) did not influence the snails' movement. Our results suggest that snail populations separated by paved roads with high traffic densities may be isolated from each other.

Beauchamp, D. E. 1970. Big game investigations: big game mortality studies. Sacramento, CA: California Department of Fish and Game; CAL. W-051-R-15/WK.PL.01/JOB 03. 6 p.

Beckemeyer, R. J. 1996. Dragonflies as roadkill. Argia. 8: 19-20.

Becker, D.; Soukkala, A.; Lipscomb, D. 1993. Wildlife and wildlife habitat impact issues and mitigation options for reconstruction of U.S. Highway 93 on the Flathead Indian Reservation. Pablo, MT: Confederated Salish and Kootenai Tribal Wildlife Program. 12 p.
Presents mitigation proposals for Highway 93, including an overpass to maintain habitat linkage for carnivores, measures to reduce painted turtle mortality in a glacial wetland, an extended bridge to maintain riparian habitat continuity, and signing in secondary wildlife crossing areas.

Becker, D. 1996. Wildlife and wildlife habitat impact issues and mitigation options for reconstruction of U.S. Highway 93 on the Flathead Indian Reservation, Montana. In: Evink, G.; Ziegler, D.; Garrett, P.; Berry, J., eds. Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors: Proceedings of the Florida Department of Transportation/Federal Highway Administration transportation-related wildlife mortality seminar; 1996 April 30-May 2; Orlando, FL. FHWA-PD-96-041. Washington, DC: U.S. Department of Transportation, Federal Highway Administration: [Pages unknown].: 85-100.
The authors review highway impacts to wetland and riparian habitats and the Evaro corridor and show a 50 meter wide wildlife overpass proposed for the Evaro corridor with drift fences. They propose signing for a secondary crossing in Ravalli Canyon. Includes Fowle's (1996) recommendations for mitigating painted turtle mortality in a glacial wetland.

Becker, D. M.; Soukkala, A. M.; Lipscomb, D. J. 1993. Evaro corridor wildlife use study and mitigation recommendations; U.S. Highway 93 project. Pablo, MT: Confederated Salish and Kootenai Tribal Wildlife Program. 24 p.
Remote cameras and snow tracking were used to document wildlife movements and highway crossings in the Evaro, Montana area. A wildlife overpass is proposed for the area where most of the crossing activity was detected.

Becker, E. F.; Grauvogel, C. A. 1991. Relationship of reduced train speed on moose-train collisions in Alaska. Alces. 27: 161-168.

Bedford, G. 1991. Record of road kill predation by the fresh water snake (*Tropidonophis mairii*). Herpetofauna. 21(2): 35-36.

Bedford, G. 1991. Two records of road kill predation by mulga snakes (*Pseudechis australis*). Herpetofauna. 21(2): 39-40.

Bedford, G.; Anthony, D. G. 1995. Road kill predation by the blackheaded python (*Aspidites melanocephalus*). Herpetofauna. 25(1):53.

Beeby, A.; Richmond, L. 1987. Adaptation by an urban population of the snail *Helix aspersa* to a diet contaminated with lead. Environmental Pollution (Series A). 46: 73-82.

Beier, P.; Loe, S. 1992. A checklist for evaluating impacts to wildlife movement corridors. Wildlife Society Bulletin. 20: 434-440.
This paper describes the important functions of wildlife corridors, identifies two classes of corridor users, and proposes a series of steps to evaluate wildlife corridors with reference to these functions and user types. Corridors provide avenues along which 1) wide-ranging animals can travel, migrate, and meet mates; 2) plants can propagate; 3) genetic interchange can occur; 4) populations can move in response to environmental changes and natural disasters; and 5) individuals can recolonize habitats from which populations have been locally extirpated. Most species that use corridors can be categorized as either "passage species" (those passing directly between 2 areas) or "corridor dwellers" (those that take several days or generations to pass through the corridor). Steps for evaluating corridors are 1) identify the habitat areas the corridor is designed to connect; 2) select several species of interest from the species present in these areas; 3) evaluate the relevant needs of each selected species; 4) for each potential corridor, evaluate how the area will accommodate movement by each species of interest; 5) draw the corridor on a map; and 6) design a monitoring program.

Beier, P. 1993. Determining minimum habitat areas and habitat corridors for cougars. Conservation Biology. 7: 95-108.
Population dynamics of cougars were simulated to predict the minimum areas and levels of immigration needed to avoid population extinction caused by demographic and environmental stochasticity for a period of 100 years. The model predicted very low extinction risk in areas as small as

2200 square kilometers. If as few as one to four animals per decade could immigrate into a small population, the probability of population persistence increased markedly. When applied to the cougar population in the Santa Ana Mountains in southern California, field data supported the models conclusion that this population was demographically unstable. Interstate and state highways limited the quality of inter- and intra-range corridors.

Beier, P. 1995. Dispersal of juvenile cougars in fragmented habitat. Journal of Wildlife Management. 59: 228-237.
There is little information on the spatiotemporal pattern of dispersal of juvenile cougars (*Felis concolor*) and no data on disperser use of habitat corridors. I investigated dispersal of radio-tagged juvenile cougars (8 M, 1 F) in a California landscape containing 3 corridors (1.5, 4.0, and 6.0 kilometers long) and several habitat peninsulas created by urban growth. Dispersal was usually initiated by the mother abandoning the cub near an edge of her home range. The cub stayed within 300 meters of that site for 13 to 19 days and then dispersed in the direction opposite that taken by the mother. Mean age at dispersal was 18 months (range 13 to 21 months). Each disperser traveled from its natal range to the farthest part of the urban-wildland edge. Dispersing males occupied a series of small (< 30% the area used by a dispersing male in the same time span), temporary (10-298 days) home ranges, usually near the urban-wildland interface, and often with its longest border along that edge. Each of the 3 corridors was used by one to three dispersers, five of the nine dispersers found and successfully used corridors, and two dispersers entered but failed to traverse corridors. Dispersing cougars will use corridors that are located along natural travel routes, have ample woody cover, include an underpass integrated with roadside fencing at high-speed road crossings, lack artificial outdoor lighting, and have less than one dwelling unit per 16 hectare.

Bekker, G. J. 1998. Habitat fragmentation and infrastructure in the Netherlands and Europe. In: Evink, G. L.; Garrett, P.; Zeigler, D.; Berry, J., eds. Proceedings of the international conference on wildlife ecology and transportation; 1998 February 10-12; Ft. Myers, FL. Tallahassee, FL: Florida Department of Transportation: 151-165.
Fragmentation of nature and the landscape by transportation infrastructure causes serious degradation of ecological values. All over Europe, the nature and scale of this problem is drawing greater attention. Nonetheless, new motorways are still cutting through valuable natural areas. In the Netherlands, on of the stated aims of nature policy, as well as its integration in infrastructure policy, is to control fragmentation. The InfraEcoNetwork Europe has been established to enhance defragmentation in Europe. One of the aims of this cooperative venture is to promote an exchange of information on developments in this field. Examples of collaboration and measures implemented in some of the countries involved demonstrate that the problem is widely recognized. Defragmentation measures require a national-level approach that must be elaborated at the regional level. A broad range of measures are available for reducing and mitigating fragmentation. Utilization of the measure differs with shape, design, and connection with the surrounding environment.

Belant, J. L. 1995. Moose collisions with vehicles and trains in northeastern Minnesota. Alces. 31: 45-52.
The author discusses moose mortality due to train and vehicle accidents in northeastern Minnesota. Data are presented on the number of moose killed by vehicles and trains, the time of year in which most accidents occur (June through September), and the sex and age ratio of moose killed (no differences were seen between the sexes or between age groups).

Bell, J. H.; Lauer, J. L.; Peek, J. M. 1992. Habitat use patterns of white-tailed deer, Umatilla River, Oregon. Northwest Science. 66: 160-171.
Habitat use of white-tailed deer (*Odocoileus virginianus ochrourus*) along the Umatilla River in northeastern Oregon was investigated from January 1985 to July 1986. Twelve radio-collared deer were located 1,148 times to determine habitat use. Plant communities used most in winter were dominated by Douglas hawthorn (*Crataegus douglasi*), ponderosa pine (*Pinus ponderosa*), Douglas fir (*Pseudotsuga menziesii*), and black cottonwood (*Populus trichocarpa*). A model predicted that 50%, 75%, and 95% of use would occur within 44 meters, 99 meters, and 248 meters of cover, respectively, which obscured 90% of a standing deer. The majority of relocations occurred more than 1600 meters from main roads.

Retention of existing mature ponderosa pine-Douglas fir and cottonwood-ponderosa pine communities, and restriction of access to these areas in winter will help maintain white-tails in this area.

Bellis, E. D.; Graves, H. B. 1971. Collision of vehicles with deer studied on Pennsylvania interstate road section. Highway Research News. 43: 13-17.
They evaluated deer roadkill rates and distribution along an 8 mile stretch of interstate highway. Road mortality was higher in spring and fall, and lower in winter and summer. Kill sites were not correlated with vegetation, though they do discuss anecdotal analysis of landscape characteristics of kill concentration areas, including areas with medians and right-of-way edges elevated relative to road surface, planted median strips, and forage availability along right-of-ways.

Bellis, E. D.; Graves, H. B. 1971. Deer mortality on a Pennsylvania interstate highway. Journal of Wildlife Management. 35: 232-237.
During 14 months 286 white-tailed deer were killed by vehicles on an 8 mile section of I-80 in central Pennsylvania. Mortality among fawns and yearlings was not significantly different between the sexes, but among adults many more females than males were killed. Mortality was highest in the fall, high in spring, and low in summer and winter. The numbers killed per month were strongly correlated with the numbers seen grazing on the planted right-of-way. Mortality was highest in sections of highway that lay in troughs formed by steep median strips and steep rights-of-way, where troughs ended by a lowering of the median strips, and through flat areas where both sides of the highway and the median strip provided good pasture.

Bellis, E. D.; Graves, H. B. 1978. Highway fences as deterrents to vehicle-deer collisions. Transportation Research Record. 674: 53-58.

Belz, A. 1988. Waterbirds and highways. Charadrius. 24(2): 111-112.

Bennett, A. F. 1990. Habitat corridors and the conservation of small mammals in a fragmented forest environment. Landscape Ecology. 4: 109-122.
This study investigated the influence of roadside corridors on terrestrial mammal distribution in a fragmented forest landscape in southwestern Victoria, Australia. Corridors were found to facilitate continuity between otherwise isolated populations of small mammals in two ways: firstly, by providing a pathway for the dispersal of single animals between patches; and secondly, by enabling gene flow through populations resident within the corridors.

Bennett, A. F. 1990. Habitat corridors: their role in wildlife management and conservation. Victoria, Australia: Department of Conservation and Environment. 37 p.

Bennett, A. F. 1991. Roads, roadsides, and wildlife conservation: a review. In: Saunders, D. A.; Hobbs, R. J., eds. Nature conservation 2: the role of corridors. Chipping Norton, Australia: Surrey Beatty and Sons: 99-117.

Bennett, A. F.; Henein, K.; Merriam, G. 1994. Corridor use and the elements of corridor quality: chipmunks and fencerows in a farmland mosaic. Biological Conservation. 68: 155-165.

Benson, R. H. 1996. The effect of roadway traffic noise on territory selection by golden-cheeked warblers. Journal of the Acoustical Society of America. 99(4/2): 25-27.
Dendroica chrysoparia in Texas.

Bereszynski, A. 1980. Studies on mortality of birds killed on public roads. Roczniki Akademii Rolniczej W Poznaniu. 22: 3-10.

Berg, A.; Part, T. 1994. Abundance of breeding farmland birds on arable and set-aside fields at forest edges. Ecography. 17: 147-152.
The aim with this study was to investigate whether abundance of farmland birds on fields at forest edges were associated with 1) type of field (young set-aside vs arable fields), 2) the length and structure of the field-forest edge zone, or 3) with residual habitats such as habitat islands, ditches, roads, etc. Twenty-eight farmland bird species (all nesting and/or foraging on open fields) were censused during the breeding season on 48 plots (open fields with adjoining forest edges) in the central parts of Sweden, covering a total area of 595 hectares. Skylark *Alauda arvensis*, linnet *Carduelis cannabina*, whitethroat *Sylvia communis* and whinchat *Saxicola rubetra* were found in significantly higher numbers in set-aside-plots than cereal ones. However, the most important factor explaining variation in the abundance of most species was the structure of the field-forest ecotone, with the length of shrubby southern deciduous forest edges being the most important factor in seven of the species. Mixed forest edges seemed to be of some importance for the abundance of three species, while associations between abundance and length of the other deciduous and coniferous field-forest ecotones only were significant for one species each. Skylarks, white wagtails *Motacilla alba* and whinchats were positively associated to ditches and yellowhammers *Emberiza citrinella* and linnets were significantly associated to habitat islands. The observed preferences for set-asides and shrubby field forest edges are suggested to be results of reduced predation risk and increased food abundance

Bergerud, A. T.; Jakimchuk, R. D.; Carruthers, D. R. 1983. The buffalo of the north: caribou (*Rangifer tarandus*) and human developments. Arctic. 37(1): 7-22.

Bergin, T. M.; Best, L. B.; Freemark, K. E. 1997. An experimental study of predation on artificial nests in roadsides adjacent to agricultural habitats in Iowa. Wilson Bulletin. 109(3): 437-448.
We quantified predation on artificial nests in Iowa roadsides and examined the relationships between nest predation and characteristics of roadsides. Transects consisting of 10 nests (five in the foreslope and five the in backslope) were set up in 136 roadsides in six watersheds in south-central Iowa. Most roadsides had herbaceous vegetation with fences (67%); fewer were wooded (18%) or had herbaceous vegetation without fences (15%). Most roads were gravel (80%), and most roadsides were adjacent to row crops (63%). Average total nest predation per transect was 23% (SE = 2), ranging from 0 to 100%. Nest predation was categorized into one of three outcomes: disappearance of eggs without disturbance to the nest bowl (39%), disappearance of eggs with disturbance to the nest bowl (17%), and broken or crushed egg shell fragments in or near the nest bowl (44%). Wooded roadsides and herbaceous roadsides with fences had significantly greater nest predation than herbaceous roadsides without fences for disappearance of eggs without disturbance to the nest bowl. Backslopes had significantly greater nest predation than foreslopes for all outcome categories except the disappearance of eggs with disturbance to the nest bowl. Wooded roadsides and herbaceous roadsides with fences along the backslope may provide cover and travel corridors for mammalian predators or elevated perches for avian predators.

Beringer, J. J. 1986. Habitat use in response to roads by black bears in Harmon den, Pisgah National Forest, North Carolina. Knoxville: University of Tennessee. 103 p. M.S. thesis.

Beringer, J. J.; Seibert, S. G.; Pelton, M. R. 1988. Incidence of road crossing by black bears on Pisgah National Forest, North Carolina. International Conference on Bear Research and Management. 8: 85-92.
We examined the reactions of 24 radio-tagged black bears to roads on the Harmon Den area of Pisgah National Forest, North Carolina during 1984 to 1987. The number of times roads were crossed by bears was related to the road density within their home range, and to the traffic volume associated with these roads. Bears crossed roads with 5 to 20 and 50 to 100 vehicles per day with equal frequency. Bears strongly avoided ($P<0.0001$) roads with >10,000 vehicles per day as the density of these roads in their home range increased. Bear crossings of roads with 5 to 20 vehicles per day increased as road density increased. Bears were found to cross roads with greater frequency during daylight hours than at night. The potential adverse effects of human activities such as timber management and hunting are discussed in relation to different types and uses of roads.

Bernardino, F. S.; Dalrymple, G. H. 1992. Seasonal activity and road mortality of the snakes of the Pa-hay-okee wetlands of Everglades National Park. Biological Conservation. 62: 71-75.
The composition and activity of the snake community of the Pa-hay-okee wetlands of Everglades National Park is described. The seasonal activity of the snakes was closely related to fluctuations in the water table. Periods of greatest snake activity coincided with the periods of greatest human visitation. Seventy-three percent of all snakes observed on the park's main road were either injured or dead. Management options available to decrease the rate of mortality of snakes include 1) the construction of wildlife underpasses, 2) temporarily closing the road on the main migratory nights, and 3) installation of reduced speed zones.

Berry, K. H. 1980. A review of the effects of off-road vehicles on birds and other vertebrates. Ogden, UT: U.S. Department of Agriculture, Forest Service; Gen. Tech. Rep. INT-86. 467 p.

Bertch, B. 1991. Monitoring program mitigation measures: Trans-Canada Highway twinning. Summary report. Banff, Alberta: Parks Canada, Banff National Park Warden Service. 29 p.

Berthoud, G. 1980. The hedgehog (*Erinaceus europaeus*) and the roads. Terre Vie. 34(3): 361-372.

Bider, J. R. 1968. Animal activity in uncontrolled terrestrial communities as determined by a sand transect technique. Ecological Monographs. 38: 269-308.

Blair, R. M.; Hays, J. A.; Brunett, L. 1963. Stream-crossing structure deer fence. Journal of Wildlife Management. 27: 129-132.
Summarized in Foster & Humphrey 1992, describes a flood-proof deer fence.

Blake, D.; Hutson, A. M.; Racey, P. A. and others. 1994. Use of lamplit roads by foraging bats in southern England. Journal of Zoology. 234(Part: 3): 3-462.
Roads illuminated by white streetlamps attracted three times more foraging bats (mostly *Pipistrellus pipistrellus*) than did roads lit by orange streetlamps or unlit roads (3.2, 1.2 and 0.7 bat passes/km, respectively). More insects flew around white lamps than around orange lamps (mean 0.67 and 0.083 insects per lamp, respectively). The mean number of bat passes recorded in any I-kilometer section of road was positively correlated to the number of white streetlamps along the section, and also, independently, to the amount of trees and hedgerows. Bat activity was not related to the number of houses along the road, ambient temperature or cloud cover. The attractive effect of the lamps on the bats was diminished in windy weather.

Bleich, V. C.; Wehausen, J. D.; Holl, S. A. 1990. Desert-dwelling mountain sheep: conservation implications of a naturally fragmented distribution. Conservation Biology. 4(4): 383-390.
Discusses interpopulation dispersals of desert bighorn and argues for the maintenance of corridors in 'non-traditional habitat' to allow for these dispersals.

Blodget, Bradford G. 1978. The effect of off-road vehicles on least terns and other shorebirds. Boston: University of Massachusetts. 79 p. M.S. thesis.

Boarman, W. I.; Sazaki, M. 1996. Highway mortality in desert tortoises and small vertebrates: success of barrier fences and culverts. In: Evink, G.; Ziegler, D.; Garrett, P.; Berry, J., eds. Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors: Proceedings of the Florida Department of Transportation/Federal Highway Administration transportation-related wildlife mortality seminar; 1996 April 30-May 2; Orlando, FL. FHWA-PD-96-041. Washington, DC: U.S. Department of Transportation, Federal Highway Administration: 169-173.
This report describes results of monitoring drift fences and passage culverts installed for desert tortoises. Desert tortoise population density was reduced within 0.4 to 0.8 kilometers of the highway. They found 88% fewer vertebrate carcasses and 93% fewer tortoise carcasses in the fenced sections of highway. They used PIT tags attached to the carapace of the tortoises to monitor movement through

culverts. They determined that two tortoises crossed through culverts ten times during the first 6 months. Tracks of coyote, kit fox, jackrabbit, ground squirrel, kangaroo rats, snakes and lizards were also detected in culverts.

Boer, A. H. 1990. Spatial distribution of moose kills in New Brunswick. Wildlife Society Bulletin. 18: 431-434.
Roads provided hunter access. Ninety-two percent of moose killed by hunters were within 1 kilometer of a road.

Boinski, S.; Sirot, L. 1997. Uncertain conservation status of squirrel monkeys in Costa Rica, *Saimiri oerstedi oerstedi* and *Saimiri oerstedi citrinellus*. Folia Primatologica. 68(3-5): 181-193.
Central American squirrel monkeys, *Saimiri oerstedi*, have never been abundant. This species is apparently extinct in Panama and nearly so in Costa Rica. Less than 4,000 are estimated to survive in Costa Rica. In recent years only a limited number of squirrel monkey troops have been documented outside of two Costa Rican national parks. Parques Nacionales Corcovado and Manuel Antonio. Numerous factors contribute to a pessimistic prognosis for this species, most importantly, the continued deforestation and tourist development with concomitant demands on prime squirrel monkey habitat from hotels, restaurants, roads, and vacation villas in the Pacific Wet Lowland habitat of squirrel monkeys. We also highlight features of the natural history of this species most relevant to conservation efforts with the goal of enhancing the success of surveys and maintenance and breeding of captive groups.

Bonar, R. L. 1987. Coquihalla phase 11: Merritt-Kamloops highway extension wildlife impact study. 2nd year report. Kamloops, B.C.: Alces Wildlife Research; Unpublished report. [Pages unknown].

Bonds, B. 1996. Yellowstone to Cody reconstruction project. In: Evink, G.; Ziegler, D.; Garrett, P.; Berry, J., eds. Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors: Proceedings of the Florida Department of Transportation/Federal Highway Administration transportation-related wildlife mortality seminar; 1996 April 30-May 2; Orlando, FL. FHWA-PD-96-041. Washington, DC: U.S. Department of Transportation, Federal Highway Administration: 108-115.
Describes mitigation measures being included in highway reconstruction projects in Wyoming. Measures include reduced shoulder width, reduced speed limits, and minimization of vegetation disturbance during construction.

Booth, C. J.; Reynolds, P. 1984. Great skuas scavenging on Orkney roads. British Birds. 7(8):358.

Borton, W. L. 1984. An analysis of deer crossing warning signs. Lansing, MI: Michigan Department of Transportation, Traffic and Safety Division; TSD-550-84. 37 p.
Accident rates at locations where signs were installed showed a greater reduction in deer - vehicle collisions than was experienced across the counties in which the signs were located (signs had a positive effect in reducing deer vehicle accidents). They recommend that deer warning signs continue to be used with special emphasis given to relocating them in a timely fashion to coincide with deer population shifts and accident concentrations.

Bottini, M. 1976. Initial effects of highway fencing and wildlife underpasses on elk movement and behavior in Banff National Park. Vancouver, BC: The University of British Columbia; Unpublished report. [Pages unknown].

Bottini, M. 1987. Elk roadkills on the Trans-Canada Highway in Banff National Park. Banff, Alberta: Banff National Park; Unpublished report. [Pages unknown].

Bourquin, J. D.; Meylan, A. 1982. Small mammals communities along divided highways: faunas and examples of spatial distribution of *microtus arvalis* (Pallas). Revue Suisse Zoology. 89(4): 977-991. In French.

Bowles, A. E. 1995. Responses of wildlife to noise. In: Knight, R. L.; Gutzwiler, K. J., eds. Wildlife and recreationists: coexistence through management and research. Covelo, CA: Island Press: 109-156.

Boyle, S. A.; Samson, F. B. 1985. Effects of nonconsumptive recreation on wildlife: a review. Wildlife Society Bulletin. 13(2): 110-116.
The authors reported effects on birds, mammals, and herpetofauna from hiking and camping, boating, wildlife observation and photography, off-road vehicles, snowmobiles, spelunking, swimming, and rock climbing. Research needs and management implication are presented.

Brandenburg, D. M. 1996. Effects of roads on behavior and survival of black bears in coastal North Carolina. Knoxville: University of Tennessee. 95 p. M.S. thesis.

Brattstrom, B. H.; Bondello, M. C. 1983. Effects of off-road vehicle noise on desert vertebrates. In: Webb, R. H.; Wilshire, H. H., eds. Environmental effects of off-road vehicles: impact and management in arid regions. New York: Springer-Verlag: 167-206.
Studies in the California desert indicate that ORV activity represents disruptive and often destructive influences on native wildlife. Noise of dune buggies and motorcycles 1) caused hearing losses in animals with little or no recovery, 2) interfered with their ability to detect predators, and 3) caused behavior in an unnatural manner that put the animal in a situation which could result in death.

Braun, M. 1991. Influence of the roadside design on the biotope interlacing in intensively agriculturally used areas. The example of the yellow-bunting and the corn-bunting. [Location of publisher unknown]: Foreign Technology Fach Informations Zentrum Energie Physik 45 p.
The significance of the roadside design for the protection of yellow-hammer and grey-hammer in intensively agriculturally used areas was investigated. For this reason, the existing stock of yellow-hammers and grey-hammers at roads and ways was mapped in differently structurized agricultural areas. The settlement density of both sorts agree with values determined by other authors for similarily structurized landscapes. The traffic load of the roads was obtained from maps. It turned out, that both sorts strongly prefer roads with low traffic load. The breeding-place of the yellow-hammer is always located in the ditch. The grey-hammer, however, broods not only in the ditch but also up to 100 meters far away of the road in the agriculturally used area. For both sorts the existence of well hidden breeding-places is of great importance. Measures are recommended to create such breeding-places contributing to the survival of yellow-hammer and grey-hammer.

Brehm, K. 1989. The acceptance of 0.2-meter tunnels by amphibians during their migration to the breeding site. In: Langton, T. E. S., ed. Amphibians and roads. Proceedings of the toad tunnel conference, 1989 January 7-8; Rendsburg, Federal Republic of Germany. Shefford, England: ACO Polymer Products Ltd: 29-42.

Bright, P. W. 1993. Habitat fragmentation - problems and predictions for British mammals. Mammal Review. 23: 101-111.

Brittingham, M. C.; Temple, S. A. 1983. Have cowbirds caused forest songbirds to decline? BioScience. 33: 31-35.

Brocke, R. H.; O'Pezio, J. P.; Gustafson, K. A. 1990. A forest management scheme mitigating impact of road networks on sensitive wildlife species. Is forest fragmentation a management issue in the northeast? GTR-NE-140. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Station: 13-17.

Brody, A. J.; Pelton, M. R. 1989. Effects of roads on black bear movements in western North Carolina. Wildlife Society Bulletin. 17: 5-10.

Broekhuizen, S.; Derckx, H. 1996. Passages for badgers and their efficacy. Zeitschrift fur Jagdwissenschaft. 42(2): 134-142. In German.

During the past decades the percentage of badgers falling victim to traffic accidents in the Netherlands had rapidly climbed to over 12% annually by the early 1990s. Along with other endangering factors this loss was seen as a threat to the survival of the badger population. An important measure to reduce the number of traffic victims was the construction of badger passages together with the fencing of roads along these passages. Free land observations showed that these pipes with a diameter of 30-40 centimeters were still attractive to badgers even if their lengths exceeded 100 meters. Controls showed that the effectiveness of these passages was highly dependent upon the quality and the length of the adjacent fencing. The proper construction and careful maintenance of the passages and especially the fences are prerequisites for their efficacy. Despite the construction of more than 200 passages the numbers of badgers killed in traffic accidents increased annually by more than 12% during the first half of this decade. On the other hand the badger population has also increased although a quantitative determination of this increase is still lacking. Hence, an evaluation of whether the construction of badger passages and adjacent fencing led to a decrease in the percentage of badgers killed by vehicles is not possible. The passages are also used by foxes, cars, (stone) martens polecats, weasel, minks, hedgehogs, rabbits and various species of mice.

Brown, C. T.; Binkley, D. 1994. Effect of management on water quality in North American forests. Gen. Tech. Rep. GTR-RM-248. Ft. Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station 27 p.
Sediment is the main concern regarding water quality in forested watersheds in North America. High suspended sediment levels, and adverse changes in stream channels, are potential problems in several regions, especially after road construction, and some timber harvesting and grazing practices.

Brown, R. J.; Brown, M. N.; Pesotto, B. 1986. Birds killed on some secondary roads in Western Australia. Corella. 0(4): 118-122.

Brown, R. L.; Smith, W. T.; Cameron, R. D. 1986. Big game investigations: distribution and movements of caribou in relation to the Kuparuk development area. Anchorage, AK: Alaska Department of Fish and Game; AK W-021-2/Job 3.30R. 50 p.
The objectives of this report were to determine the locations of caribou crossings of the road(s) and pipelines, and to determine between-year differences in the distribution, movements, and sex/age composition of caribou during precalving, calving, post-calving and insect periods in or near the Kuparuk development area.

Browne, B. 1984. Work plan for wildlife study along the Bow Valley from Sunshine turn-off to Castle junction - Trans-Canada Highway twinning Phase III. Banff, Alberta: Parks Canada, Banff National Park Warden Service 17 p.

Browne, B.; Wackerle, J. 1985. Monitoring program - mitigative measures. Trans-Canada Highway twinning. Phase I - Kilometer 0 - 11.4. Second progress report. Banff, Alberta: Parks Canada, Banff National Park Warden Service. 56 p.

Browne, B. 1986. Monitoring program mitigative measures: Trans-Canada Highway twinning. Phase I - Kilometer 0 - 11.4. Third progress report. Banff, Alberta: Parks Canada, Banff National Park Warden Service 49 p.

Browne, B.; Bertch, B.; Everts, K. 1988. The requirement for wildlife mitigation measures for the proposed improvements to the Trans-Canada Highway - Sunshine Road to the Icefields Parkway (Km 26 to Km 75). Banff, Alberta: Parks Canada, Banff National Park Warden Service. [Pages unknown].

Brunelle. 1995. A 2.5 liter 4WD collecting net for insects and pedestrians. Argia. 7: 21-22.

Buchanan, Joseph B. 1987. Seasonality in the occurrence of long-tailed weasel road-kills. Murrelet. 68(2): 67-68.

Buck, D. T.; Dobrick, R. 1989. The behaviour of migrating anurans at a tunnel and fence system. In: Langton, T. E. S., ed. Amphibians and roads. Proceedings of the toad tunnel conference; 1989 January 7-8; Rendsburg, Federal Republic of Germany. Shefford, England: ACO Polymer Products Ltd.: 137-143.

Bugbee, R. E. 1945. A note on the mortality of snakes on highways in western Kansas. Transactions of the Kentucky Academy of Science. 47: 373-374.

Bunyan, R. 1989. Monitoring program - mitigative measures. Trans-Canada Highway twinning. Phase II - Km 11.4 - 27.0. First Progress Report. Banff, Alberta: Parks Canada, Banff National Park Warden Service 57 p.

Bunyan, R. 1990. Monitoring program - wildlife mitigation measures: Trans-Canada Highway twinning. Phase II - Km 11.4 - 27.0. Final Report. Banff, Alberta: Parks Canada, Banff National Park Warden Service 52 p.

Burger, J.; Gochfeld, M. 1992. Vulnerability and mortality of young Australian magpies on roads. Wilson Bulletin. 04(2): 365-367.

Burgess, Robert M. 1992. The relative influence of oil-development related disturbance and environmental factors on activity budgets of brood-rearing snow geese at Howe Island, Alaska. [Abstract]. North American Arctic Goose Conference Workshop Number 7. Fairbanks, AK: Biological Research: 35-35.

Burke, R. C.; Sherburne, J. A. 1982. Monitoring wildlife populations and activity along I-95 in northern Maine before, during and after construction. Transportation Research Record. 859: 1-8.
They conducted breeding bird, small, and medium sized animal surveys before, during, and after highway construction. Bird breeding pair density declined over the survey period, however they attribute the decline to a general trend for bird populations in Maine during those years. Bird species composition did change. Small mammal trapping rate did not change, but species composition did. They conducted snow surveys and pellet group counts for larger mammals. Post-construction deer use shifted away from the highway. They conclude that the primary impact of the interstate highway construction is immediate loss of habitat and note a change in species composition due to habitat conversion.

Burnett, S. E. 1992. Effects of a rainforest road on movements of small mammals: mechanisms and implications. Wildlife Research. 19: 95-104.
Live-trapping was used to study the effects of a road on the movements of four species of terrestrial and scansorial rainforest mammals at Mount Spec, north Queensland (Australia). When baited traps were set on both sides of the road during grid-trapping, the road-crossing rate of *Uromys caudimaculatus* (20% of recorded movements) was significantly greater than that of *Rattus fuscipes* and *Antechinus flavipes* (1.8% and 5.2% of movements, respectively). No *Melomys cervinipes* were recorded crossing the road under these conditions. *R. fuscipes, M. cervinipes* and *A. flavipes* were induced to cross the road more often by placing baited traps on only one side of the road during the baiting experiment. The crossing rate of *R. fuscipes* was also increased by translocating individuals across the road. I attribute the inhibition of movement caused by roads to psychological or sociological characteristics of the species or the individual, rather than to an effect of a physical barrier per se. My data suggest that the threat of genetic isolation of populations of these species dissected by roads less than 12 meters wide is slight. This study represents a best-case scenario; less-mobile species or wider roads may result in genetic isolation. Measures are suggested that would be expected to alleviate the barrier effects of roads where they may occur.

Bury, R. B.; Luckenbach, R. A.; Busack, S. D. 1977. Effects of off-road vehicles on vertebrates in the California desert. Washington, DC: U.S. Fish and Wildlife Service; Wildl. Res. Rep. 8. 23 p.

Bury, R. B.; Roger, A. L. 1983. Vehicular recreation in arid land dunes: biotic responses and management alternatives. In: Webb, R. H.; Wilshire, H. G., eds. Environmental effects of off-road vehicles: impacts and management in arid regions. New York: Springer-Verlag: 207-221.

Bury, R. L. 1978. Impacts of snowmobiles on wildlife. Transactions of the North American Wildlife Natural Resource Conference. 43: 149-156.

Busack, S. D.; Bury, R. B. 1974. Some effects of off-road vehicles and sheep grazing on lizard populations in the Mojave Desert. Biological Conservation. 6(3): 179-183.

Bush; Browne-Cooper, R.; Maryan, B. 1991. Some suggestions to decrease reptile roadkills in reserves with emphasis on the western Australian wheatbelt. Herptofauna. 21(2): 23-24.

Cale, P. 1990. The value of road reserves to the avifauna of the central wheatbelt of western Australia. Proceeding of the Ecological Society of Australia. 16: 359-367.

Caletrio, G. J. 1992. Provisional report of the mortality of vertebrates on the roads of Valencia, September 1991. In: Lopez, Redondo, ed. I jornadas para el estudio y prevencion de la mortalidad de vertebrados en carreteras, Madrid, 5 y 6 de Octubre de 1991. Tomo 2. [Sessions in the study of prevention of road mortalities of vertebrates, Madrid, 5 and 6 October, 1991. Volume 2.]. Ambiental, Madrid: Coordinadora de Organizacciones de Defensa: 222-230.

Caletrio, J.; Fernandez, J. M.; Lopez, J.; Roviralta, F. 1996. Spanish national inventory on road mortality of vertebrates. Global Biodiversity. 5: 15-18.

Calvo, R. N.; Silvy, N. J. 1996. Key deer mortality, U.S. 1 in the Florida Keys. In: Evink, G.; Ziegler, D.; Garrett, P.; Berry, J., eds. Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors: Proceedings of the Florida Department of Transportation/Federal Highway Administration transportation-related wildlife mortality seminar; 1996 April 30-May 2; Orlando, FL. FHWA-PD-96-041. Washington, DC: U.S. Department of Transportation, Federal Highway Administration: 287-296.
Road mortality is 75-80% of all Key deer deaths. This report provides a list of mitigation options, but the options had not been ranked by the time the report was submitted. They did not mention crossing structures.

Camby, A.; Maizert, C. 1985. Permeabilite des routes et autoroutes vis-a-vis des mammiferes carnivores: example des etudes menees dans les Landes de Gascogne par radio-poursuite. Routes et faune sauvage. Strasbourg: Act. du colloque. Min. Equipe. Loge. Amenage. terr. Transp.: 183-196.

Cameron, R. D.; Whitten, K. R. 1980. Big game investigations: effects of the Trans-Alaska Pipeline on caribou movements. Anchorage, AK: Alaska Department of Fish and Game 27 p.
Results of continued aerial surveys of caribou in the central Arctic region and of road surveys along the Trans-Alaska Pipeline (TAP) are compared with data from previous years. Herd identity, general numbers, productivity, and seasonal movement patterns of caribou within the vicinity of TAP were determined. Movement behavior of caribou which encounter the haul road, TAP, and construction-related activities were characterized. The following reports are appended 1) movements of collared caribou in relation the petroleum development on Alaska's Arctic slope, and 2) survey-inventory progress report, central Arctic herd, 1980-81.

Cameron, R. D.; Whitten, K. R. 1980. Influence of the Trans-Alaska pipeline corridor on the local distribution of caribou: Alaska game management and investigations. Anchorage, AK: Alaska Department of Fish and Game; W-017-R. 484 p.

The combined results indicate caribou avoidance of the TAP corridor and associated areas of oil development, a response which is strongest for cows with neonatal calves.

Cameron, R. D.; Whitten, K. R.; Smith, W. T. 1981. Big game investigations: responses of caribou to petroleum-related development on Alaska's arctic slope. Anchorage, AK: Alaska Department of Fish and Game 79 p.
Systematic aerial surveys of caribou in the central Arctic region were conducted on 27-30 April and again on 3-5 November 1981, with the objectives of (1) determining seasonal changes in the distribution and group sex/age composition of caribou in the vicinity of the Trans- Alaska Pipeline (TAP) corridor, to identify and assess local abnormalities; (2) determine the location and direction of corridor crossings by caribou; and (3) characterize the behavioral responses of caribou to Dalton Highway, TAP, traffic, and human activity. The following reports are appended: population dynamics of the central Arctic herd, 1975-1981; responses of caribou to industrial development on Alaska's Arctic slope; survey-inventory progress report on the central Arctic herd; survey observations on the calving grounds of the central Arctic herd, 11-14 June 1981; caribou and petroleum development, November 1982 (draft issue paper); and north slope State Lands Guideline document, 9 January 1981 (excerpts).

Cameron, R. D.; Whitten, K. R.; Smith, W. T. 1985. Big game investigations: effects of the Trans-Alaska pipeline on the distribution and movements of caribou. Anchorage, AK: Alaska Department of Fish and Game 27 p.
The comparative results of caribou surveys conducted by air and along the Dalton Highway between 1975 and 1982 are highlighted.

Cameron, R. D.; Reed, D. J.; DAU, J. R.; Smith, W. T. 1992. Redistribution of calving caribou in response to oil field development on the arctic slope of Alaska. Arctic. 45(4): 338-342.
Aerial surveys were conducted annually in June 1978-87 near Prudhoe Bay, Alaska, to determine changes in the distribution of calving caribou (*Rangifer tarandus granti*) that accompanied petroleum-related development. With construction of an oil field access road through a calving concentration area, mean caribou density (no./km^2) decreased from 1.41 to 0.31 ($P = 0.05$) within 1 kilometer and increased from 1.41 to 4.53 ($P = 0.04$) 5-6 kilometers from the road. Concurrently, relative caribou use of the adjacent area declined ($P < 0.02$), apparently in response to increasing surface development. We suggest that perturbed distribution associated with roads reduced the capacity of the nearby area to sustain parturient females and that insufficient spacing of roads may have depressed overall calving activity. Use of traditional calving grounds and of certain areas therein appears to favor calf survival, principally through lower predation risk and improved foraging conditions. Given the possible loss of those habitats through displacement and the crucial importance of the reproductive process, a cautious approach to petroleum development on the Arctic slope is warranted.

Cameron, R. D.; Smith, W. T. 1992. Wildlife research and management. distribution and productivity of the central Arctic caribou herd in relation to petroleum development: case history studies with a nutritional perspective. Anchorage, AK: Alaska Department of Fish and Game; AK W-023-5/Study 3.35. 40 p.
The following reports are appended: (1) redistribution of calving caribou in response to oilfield development on the Arctic slope of Alaska (R.D. Cameron, D.J. Reed, J.R. Dau, and W.T. Smith); (2) distribution and movement of caribou in relation to roads and pipelines, Kuparuk development area, 1978-90 (W.T. Smith, R.D. Cameron, and D.J. Reed); and (3) calving success of female caribou in relation to body weight (R.D. Cameron, W.T. Smith, S.G. Fancy, K.L. Gerhart, and R.G. White).

Cameron, R. D.; Lenart, E. A.; Reed, D. J. and others. 1995. Abundance and movements of caribou in the oilfield complex near Prudhoe Bay, Alaska. Rangifer. 15(1): 3-7.
We examined the distribution and movements of 141 radiocollared female caribou (*Rangifer tarandus granti*) of the central Arctic herd during summer, 1980-1993. Numbers of caribou locations within each of five quadrats along the arctic coast were totaled separately for days during which insects were active and inactive, and numbers of east-west and west-east crossings of each quadrat mid-line were determined from sequential observations. Both abundance and lateral movements of radiocollared

females in the quadrat encompassing the intensively-developed Prudhoe Bay oilfield complex were significantly lower than in other quadrats ($P < 0.001$ and $P < 0.00001$, respectively). Avoidance of, and fewer movements within, the complex by female caribou are ostensibly in response to the dense network of production and support facilities, roads, above-ground pipelines, and the associated vehicular and human activity. Impaired access to this area constitutes a functional loss of habitat.

Camp, M.; Best, L. B. 1993. Bird abundance and species richness in roadsides adjacent to Iowa rowcrop fields. Wildlife Society Bulletin. 21: 315-325.
We studied bird use of roadsides adjacent to rowcrop fields in central Iowa from May through August, 1990 and 1991. Thirty-five bird species were seen in roadsides, compared with 26 species in rowcrop fields. Bird abundance also was greater in roadsides than in rowcrop fields. Few bird species showed a preference for roadsides with native-mix versus exotic grasses or for burned versus unburned roadsides, but the abundance of some birds was related to vegetation height and vertical density in roadsides. American robin, brown thrasher, brown-headed cowbird, and vesper sparrow abundance, as well as total bird abundance, were greater in roadsides in 1990 than in 1991. Horned lark, brown-headed cowbird, vesper sparrow, and total bird abundance was greater in fields in 1990 than in 1991.

Camp, M.; Best, L. B. 1994. Nest density and nesting success of birds in roadsides adjacent to rowcrop fields. American Midland Naturalist. 131: 347-358.
Intensive rowcrop farming in the Midwest has eliminated much wildlife grassland habitat; yet some linear habitat remains in areas such as roadsides. To determine the importance of roadsides to nesting birds in intensively farmed areas, this study evaluated nest densities and nesting success of birds in roadsides in central Iowa during 1990 and 1991. One hundred and twenty nests of eight species were found in 34 roadsides (10.2 ha). Red-winged blackbird (*Agelaius phoeniceus*) nest density was greatest in roadsides with tall dense vegetation; vesper sparrow (*Pooecetes gramineus*) nests were most dense in areas of sparse vegetation. Gray partridge (*Perdix perdix*) and ring-necked pheasant (*Phasianus colchicus*) nest densities were greatest in roadsides with the most residue cover. Red-winged blackbirds usually placed their nests in the bottom or in the fencerow of a roadside; all vesper sparrows nested in the short vegetation of the roadside nearest the road. Daily survival rates for the red- winged blackbird and for all species combined were 0.9471 and 0.9428, respectively. Fifty-five percent of red-wing nests and 52% of the nests of all species were destroyed by predation. Red-wing nests placed in forbs, shrubs and the fence were more successful than those built in grasses other than reed canarygrass (*Phalaris arundinace*). Roadside management which includes seeding native grasses and forbs in roadsides may make these areas more attractive to birds that use such habitats for nesting. Fences were used by some birds in place of vegetation for nest support and should be retained in roadsides. Periodic prescribed burns in roadsides would increase the vigor and structural heterogeneity of roadside vegetation; mowing roadsides should be discouraged except at the roadside shoulder.

Campbell, M. 1985. Traffic in toads. Countryman. 0(1): 102-105.

Canelas, L. D. 1989. First environmental impact assessment of a highway in Portugal: repercussions of European economic community directive. Environmental Impact Assessment Review. 9(4): 391-397.

Canfield, P. J. 1991. A survey of koala road kills in New South Wales. Journal of Wildlife Diseases. 27: 657-660.

Canter, L. W.; Robertson, J. M.; Westcott, R. M. 1991. Identification and evaluation of biological impact mitigation measures. Journal of Environmental Management. 33(1): 35-50.

Canters, K. 1997. Habitat fragmentation and infrastructure-proceedings of the international conference on habitat fragmentation, infrastructure and the role of ecological engineering. Delft and The Hague, The Netherlands: Ministry of Transport, Public Works and Water Management. 474 p.

Carbaugh, B.; Vaughan, J. P.; Bellis, E. D.; Graves, H. B. 1975. Distribution and activity of white-tailed deer along an interstate highway. Journal of Wildlife Management. 39: 570-581.

Collisions were more frequent in forested areas than in agricultural areas with the same deer densities. Deer were attracted to right-of-way vegetation for forage more in forested than in agricultural areas. Distribution and activity of white-tailed deer were studied on a 12.9 kilometer section of I-80 in a forested region of central Pennsylvania from May 1968 to May 1969 and on a 12.4 kilometer agricultural section of the highway from April 1968 to May 1969. Observations of deer were made from a vehicle equipped with a spotlight for nighttime observing. Over 6,500 deer were observed and categorized as to location, behavior, sex, and age. Numbers of deer seen were related to time of day, topography, vegetation, traffic, and meteorlogical factors. Most of the deer seen in the forested area were grazing on the highway rights-of-way; most of those seen in the agricultural area were grazing in fields and rarely were seen on the rights-of-way. Deer tended to move into our study areas at dawn. Neither traffic volume nor weather correlated strongly with numbers of deer seen; spring and fall were times of great deer abundance in both study areas, but vegetation type and topography were more important factors in the forested area than in the agricultural area. Feeding behavior of deer in both areas dominated all other activities. The impact of the highway itself on deer abundance and distribution and the relationship between deer activity and deer-automobile collisions are functions of highway location relative to deer requisites such as feeding and resting sites and to relative availability of feeding areas other than rights-of-way.

Carbaugh, B. T. 1970. Activity and behavior of white-tailed deer (*Odocoileus virginianus*) along an interstate highway in a forest region of Pennsylvania. University Park, PA: Pennsylvania State University. [Pages unknown]. Ph.D. thesis.

Carey, M.; Wagner, P. 1996. Salmon passages and other wildlife activities in Washington state. In: Evink, G.; Ziegler, D.; Garrett, P.; Berry, J., eds. Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors: Proceedings of the Florida Department of Transportation/Federal Highway Administration transportation-related wildlife mortality seminar; 1996 April 30-May 2; Orlando, FL. FHWA-PD-96-041. Washington, DC: U.S. Department of Transportation, Federal Highway Administration: 153-168.
Summarizes WDOT salmon passage program and briefly mentions deer roadkill monitoring and I-90 project.

Carey, M. 1998. Peregrine falcons and the Washington State Department of Transportation. In: Evink, G. L.; Garrett, P.; Zeigler, D.; Berry, J., eds. Proceedings of the international conference on wildlife ecology and transportation; 1998 February 10-12; Ft. Myers, FL. Tallahassee, FL: Florida Department of Transportation: 121-125.
Recovering populations of threatened and endangered wildlife face increased altercation to natural habitats. Peregrine falcons (*Falco peregrinus*) have demonstrated a strong ability to adapt to urban habitats. This can present a dilemma for agencies with both the responsibility to operate and maintain transportation facilities as well as the need to protect sensitive wildlife. Peregrine falcons have been nesting on an aging steel span bridge in Washington State in both 1996 and 1997, and each year the peregrine's nesting cycle has coincided with the need to complete maintenance and construction work on the bridge. Due to the short, weather driven construction season, not all maintenance activities can be completed outside of their nesting season. The Washington State Department of Transportation entered into a formal consultation with the U.S. Fish and Wildlife Service under Section 7 of the Endangered Species Act. As part of this formal consultation, a management plan was developed for the bridge. The management plan outlines previously agreed-upon conservation and mitigation measures to avoid and minimize impacts and provides a road map to help simplify the consultations between USFWS and WSDOT on this bridge. In addition, it will serve as a model for other bridge sites in Washington which become occupied by peregrine falcons.

Carlson, J. E.; Michael, J. D.; Lawrence, A. R. 1980. Off-road vehicle impacts in the Big Cypress National Preserve. Proceedings of the Second Conference on Science Research in National Parks. 9: 347-386.

Carr, Margaret H.; Zwick, Paul D.; Hoctor, Thomas; Harrell, Wesley ; Goethals, Andrea; Benedict, Mark 1998. Using GIS for identifying the interface between ecological greenways and roadway systems at the state and sub-state scales. In: Evink, G. L.; Garrett, P.; Zeigler, D.; Berry, J., eds. Proceedings of the international conference on wildlife ecology and transportation; 1998 February 10-12; Ft. Myers, FL. Tallahassee, FL: Florida Department of Transportation: 68-77.
The existence of an adopted integrated state/sub-state conservation plan, similar to the Statewide Greenways Plan being developed by the Florida Department of Environmental Protection and the Florida Greenways Coordinating Council, with funding from the Florida Department of Transportation, has great potential to help minimize environmental impacts that arise from roadway widening and new construction. Identification of the interfaces between roadways and areas of conservation interest can and has been done for Florida through the Florida Statewide Greenways System Planning Project. This paper will describe the process used by a team of researchers from the University of Florida in the development of a GIS model to design an integrated conservation system and to identify areas of overlap between the resulting system and roadways. Although the team's work included identification of a complete system comprised of an ecological sub-system and a recreational/cultural sub-system, this paper focuses on the results of the ecological system identification step and its interface with the roadway.

Carr, P. C.; Pelton, M. R. 1984. Proximity of adult female black bears to limited access roads. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies. 8 1984: 70-77.

Carver, G. 1989. An evaluation of linear wildlife openings. Mobile, AL: Alabama Game and Fish Division. [Pages unknown].; AL W-035-33/Job A and B/Study IV.
The objective was to determine the feasibility of using linear wildlife openings in wildlife management. Study openings were access roads and log landings associated with recent timber harvest on the Hollins Wildlife Management Area.

Case, R. M. 1978. Interstate highway road-killed animals: a data source for biologists. Wilson Society Bulletin. 6(1): 8-13.
They suggest using road kill rates as an index for long-term population monitoring. Monthly road kill rates along I-80 in Nebraska were highest in May and October, associated with breeding and dispersal activities. Road killed animals were not significantly correlated with average daily traffic on an annual or monthly basis. Annual road killed animals were significantly correlated with average vehicle speed.

Case, Ronald M.; Gleim, James A. 1976. Road-killed animals on Interstate-80 in Nebraska. Proceedings Nebraska Academy of Science. 86: 9-10.
During a short study along 29 miles of a Nebraska highway, high rates of road-kill were found in association with the species optimum habitat.

Chan, J. 1993. Evaluation of methods to reduce road mortality of red-sided garter snakes at Narcisse Wildlife Management Area. Manitoba, Canada: University of Manitoba. [Pages unknown]. M.S. thesis.

Channing, C. H. 1958. Highway casualties of birds and animals for one year period. Murrelet. 39: 41-42.

Chardon, J. P.; Vos, C. C. 1993. Location of tunnels for amphibians in the Netherlands. Waarnemingen Van Amfibieen En Reptielen In Nederland. 1993: 47-50.

Chardon, P.; Vos, C.; DeVries, H. 1996. The use of amphibian tunnels under roads. Levende Natuur. 97: 110-115.
The main effect of roads on amphibians is mortality by traffic. The mortality can be so high that all highways and almost all secondary roads in The Netherlands must be seen as absolute barriers (Vos and Chardon 1994). To reduce this mortality it is possible to construct amphibian tunnels under roads. The degree in which tunnels are used by amphibians depends on many factors. In this article the most important factors are discussed.

Chase, S. 1998. Road to recovery salmon restoration: the regional approach. In: Evink, G. L.; Garrett, P.; Zeigler, D.; Berry, J., eds. Proceedings of the international conference on wildlife ecology and transportation; 1998 February 10-12; Ft. Myers, FL. Tallahassee, FL: Florida Department of Transportation: 140-142.
This report summarizes Oregon's salmon recovery project, its application to other fish species, and incorporating a regional approach outside of the state.

Child, K.; Barry, S.; Aitken, D. 1991. Moose mortality on highways and railways in British Columbia. Alces. 27: 41-49.

Child, K. N. 1984. Railways and moose in the central interior of British Columbia: a recurrent management problem. Alces. 19: 118-135.

Child, K. N.; Stuart, K. M. 1987. Vehicle and train collision fatalities of moose: some management and socio-economic considerations. Swedish Wildlife Research Supplement. 1:-[Pages unknown].

Christensen, A. G.; Lyon, L. J.; Lonner, T. N. 1991. Proceedings of elk vulnerability - a symposium; 1991 April 10-12; Bozeman, MT. Bozeman, MT: Montana State University. 330 p.
Proceedings of a symposium with an emphasis on the effects of forest roads on elk habitat use.

Cifuentes, Torres A.; Garcia, Onate B. 1992. Amphibia mortality on the roads of Pontevedra Province. In: Lopez, Redondo, ed. I jornadas para el estudio y prevencion de la mortalidad de vertebrados en carreteras, Madrid, 5 y 6 de Octubre de 1991. Tomo 2. [Sessions in the study of prevention of road mortalities of vertebrates, Madrid, 5 and 6 October, 1991. Volume 2.]. Ambiental, Madrid: Coordinadora de Organizacciones de Defensa: 231-238.

Clapers, A. 1992. Mortalities and live crossings by animals on the roads of Moianes (December 1990 - August 1991). In: Lopez, Redondo, ed. I jornadas para el estudio y prevencion de la mortalidad de vertebrados en carreteras, Madrid, 5 y 6 de Octubre de 1991. Tomo 2. [Sessions in the study of prevention of road mortalities of vertebrates, Madrid, 5 and 6 October, 1991. Volume 2.]. Ambiental, Madrid: Coordinadora de Organizacciones de Defensa: 322-326.

Clark, D. R. 1979. Lead concentrations: bats vs. terrestrial small mammals collected near a major highway. Environmental Science and Technology. 13: 338-340.

Clark, D. R. 1992. Organochlorines and heavy metals in 17-year cicadas pose no apparent dietary threat to birds. Environmental Monitoring and Assessment. 20: 47-54.
Organochlorine and heavy metal concentrations in 17-year cicadas from Prince Georges and Anne Arundel Counties, Maryland (USA), were well below levels known to be harmful to birds. Cicadas contained concentrations of metals similar to or less than other local invertebrates except they contained more copper than did earthworms. Copper and lead concentrations in cicadas from one site may have been elevated by sewage plant effluent deposited during river floodings. Cicadas from the median of a major highway did not contain more lead than cicadas from non-traffic sites.

Clark, J. D.; Dunn, J. E.; Smith, K. G. 1993. A multivariate model of female black bear habitat use for a geographic information system. Journal of Wildlife Management. 57(3): 519-526.
Simple univariate statistical techniques may not adequately assess the multidimensional nature of habitats used by wildlife. Thus, we developed a multivariate method to model habitat-use potential using a set of female black bear (*Ursus americanus*) radio locations and habitat data consisting of forest cover type, elevation, slope, aspect, distance to roads, distance to streams, and forest cover type diversity score in the Ozark Mountains of Arkansas. The model is based on the Mahalanobis distance statistic coupled with Geographic Information System (GIS) technology. That statistic is a measure of dissimilarity and represents a standardized squared distance between a set of sample variates and an ideal based on the mean of variates associated with animal observations. Calculations were made with the GIS to produce a map containing Mahalanobis distance values within each cell on a 60- x 60-meter

grid. The model identified areas of high habitat use potential that could not otherwise be identified by independent perusal of any single map layer. This technique avoids many pitfalls that commonly affect typical multivariate analyses of habitat use and is a useful tool for habitat manipulation or mitigation to favor terrestrial vertebrates that use habitats on a landscape scale.

Clark, W. D.; Karr, J. R. 1979. Effects of highways on red-winged blackbird and horned lark populations. Wilson Society Bulletin. 91: 143-145.

Clayton Resources Ltd. 1989. Wildlife fencing and control on the Okanogan connector highway: a benefit cost analysis. Victoria, BC: Ministry of Transportation and Highways Environmental Services Section, Highway Engineering Branch. 32 p.
The report evaluates the benefits of fencing highway and it is noted that benefits outweighed costs. Total value of benefits over 30 years was estimated to be from $4,719,000 to $19,460,000. Cost estimate was $6,621,027.

Clergeau, P. 1993. Use of landscape ecology concepts for the development of a new type of wildlife passage. Gibier Faune Sauvage. 10: 47-57.

Clevegener, A. P. 1996. A monitoring plan for wildlife crossing structure use along the Trans-Canada Highway. Banff, Alberta: Parks Canada, Banff National Park Warden Service. 15 p.

Clevenger, A. P. 1996. Highway effects on wildlife: a research, monitoring and adaptive mitigation study. Banff, Alberta: Parks Canada, Banff National Park Warden Service; Progress Report #1. 16 p.
Describes methods and preliminary results for monitoring wildlife mitigation implemented along the Trans-Canada Highway in Banff National Park. Also describes preliminary methods for developing a landscape-based wildlife-vehicle collision model.

Clevegener, A. P. 1997. Wildlife underpass use by ungulates and large carnivores along twinned sections of the Trans-Canada Highway in Banff National Park, 1995-1997. Canmore, Alberta: Alberta Environmental Protection, Natural Resources Service. [Pages unknown].

Clevegener, A. P.; Purroy, F. J.; Campos, M. A. 1997. Habitat assessment of a relict brown bear (*Ursus arctos*) population in northern Spain. Biological Conservation. 80(1): 17-22.
We assess the habitat quality of a small remnant population of Eurasian brown bears (*Ursus arctos*) in northern Spain based on a habitat evaluation procedure and analysis of bear distribution and road density. Habitat evaluation was based on our knowledge of bear habitat requirements using a combination of radio location and sign data and analysis of four variables (forest cover, elevation, distance to nearest village, distance to nearest roadway). Herein, we use those results to calculate habitat suitability indices for 1 km^2 UTM cells over 3500 km^2 of bear range, by summing scores (from 0 to 1) for each variable. Roughly 15% of the study area was classified as high-quality bear habitat. In secondary bear range (sporadic presence) the average unpaved road density was more than twice as high compared to that in primary, year-round, range, and was highest in areas outside of the bear range. The applicability of our habitat evaluation procedure to other small remnant Eurasian bear populations is proposed.

Clevegener, A. P.; Wells, K. 1997. Proceedings of the second roads rails and the environment workshop; 1997 April 9-10; Revelstoke, B.C. Banff, Alberta: Parks Canada, Banff National Park. 101 p.

Clevenger, A. P. 1998. Permeability of the Trans-Canada Highway to wildlife in Banff National Park: importance of crossing structures and factors influencing their effectiveness. In: Evink, G. L.; Garrett, P.; Zeigler, D.; Berry, J., eds. Proceedings of the international conference on wildlife ecology and transportation; 1998 February 10-12; Ft. Myers, FL. Tallahassee, FL: Florida Department of Transportation: 109-119.
Highway mitigation measures have been designed to increase permeability and habitat connectivity for wildlife living in transportation corridors. Unfortunately, post-construction performance evaluations

are rarely carried out to determine mitigation measure effectiveness, modify them if necessary, and learn from past experiences. In Banff National Park, Alberta, 11 wildlife underpasses (WUP) were constructed during the last decade to allow wildlife movement across a 4-lane section of the Trans-Canada Highway (TCH). This paper evaluates wildlife use of the WUP and examines the importance of structural and environmental features that may enhance wildlife use of them. The results suggest that possible barrier effects of the TCH may be reduced by WUP, but long-term studies are needed to assess TCH effects on species' fitness. Park management of human activity around WUP will be crucial for success. The requirements of sensitive species should take precedence in design of quality WUP.

Codoner, N. A. 1995. Mortality of Connecticut birds on roads and at buildings. Connecticut Warbler. 5(3): 89-98.

Coggin, J. L.; Guthrie, A.; Carpenter, M. and others. 1972. Virginia upland game investigations: road game population relationship study. s.:-5.

Cole, E. K.; Pope, M. D.; Anthony, R. G. 1997. Effects of road management on movement and survival of Roosevelt elk. Journal of Wildlife Management. 61(4): 1115-1126.
Movement by elk decreased (fewer long-distance movements in response to disturbance) and survival increased when roads were gated and traffic reduced to < 5 vehicles/week in the Oregon Coast Range.

Colorado Division of Wildlife. 1980. Wildlife research report. Part one. Denver, CO: State of Colorado, Division of Wildlife. 178 p.
Methods, devices, or structures related to reducing the number of deer-vehicle accidents were evaluated or experimentally tested after obtaining preliminary data on study areas and methodology. These methods, devices, or structures were highway lighting, underpasses, overpasses, 2.44-meter fences and one-way deer gates, and deer guards. During the highway lighting study, 84 deer-vehicle accidents occurred, 45 and 39 with lights off and on, respectively. Behavioral responses of deer to the Vail deer underpass did not change substantially over the 10 years (1970-1979) of study. Five deer guard prototypes were evaluated. Highway lighting, as tested in this study, did not result in significantly fewer accidents.

Conner, R. N.; Adkisson, C. S. 1976. Concentration of foraging common ravens along the Trans-Canada Highway. Canadian Field Naturalist. 90: 496-497.

Conover, M. R.; Pitt, W. C.; Kessler, K. K. and others. 1995. Review of human injuries, illnesses, and economic losses caused by wildlife in the United States. Wildlife Society Bulletin. 23(3): 407-414.
They review animal damage of all types. In reviewing deer-automobile collisions, the draw heavily on Romin 1994. They estimate that there are >1,000,000 collisions each year (reported and unreported). Based on 726,000 reported collisions, vehicle repairs cost $1.1 billion, 29,000 human injuries occurred, and 211 fatalities.

Convisser, M. 1979. Mitigation of transportation impacts. In: Swanson, G. A., ed. The mitigation symposium: a national workshop on mitigation losses of fish and wildlife habitat; 1979 July 16-20; Fort Collins, CO. Gen. Tech. Rep. RM-65. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 71-74.

Cook, K. E.; Daggett, P. M. 1995. Highway roadkill, safety, and associated issues of safety and impact on highway ecotones. [Location of publication unknown]: Task Force on Natural Resources (A1F52), Transportation Research Board, National Research Council. 25 p.
They estimate that the total number of road killed deer each year in the U.S. is about 750,000. Most states reported that deer road kills have increased 30% to 50% over the past ten years. Increases are probably correlated with the overall increase in deer population and the number and speed of vehicles on the highways. Five factors that influence the number of animal/vehicle accidents on highways; road characteristics, driver characteristics, animal populations (e.g., seasonal activities), external factors (e.g., weather, traffic volume), other factors (e.g., escape cover). 113 people were killed in animal/vehicle

collisions in 1993. They estimate that total yearly cost of animal/vehicle collisions is about 1.2 billion a year. Effects on small and medium sized mammals are poorly documented, but they estimate tens of millions of small and medium sized animals killed each year. Birds area probably killed more often than any other type of animal. They list 18 sensitive species that suffer substantial mortality from road kill. Includes an evaluation of mitigation measures, including fencing, vegetation management, crossing structures, signing. They estimate that there are 20 million acres of roadside wildlife habitat nationally.

Cooke, A. S. 1988. Mortality of toads (*Bufo bufo*) on roads near a Cambridgeshire breeding site. British Herpetological Society. 6: 29-30.

Corbett, K. 1982. Toads and roads - conservation in action. Flycatcher. 8: 18-20.

Corbett, K. F. 1989. Amphibian fencing. In: Langton, T. E. S., ed. Amphibians and roads. Proceedings of the toad tunnel conference; 1989 January 7-8; Rendsburg, Federal Republic of Germany. Shefford, England: ACO Polymer Products Ltd.: 183-190.

Costas, R. 1991. A survey of bird mortality in several southwestern Galician roads during spring and summer. Cursos Congress University Santiago Compostela. 66: 219-230.

Cottam, C. 1931. Birds and motor cars in South Dakota. Wilson Bulletin. 43: 313-314.

Coulson, G. 1982. Road-kills of macropods on a section of highway in central Victoria. Australian Wildlife Research. 9: 21-26.
A 20 kilometer section of highway near Heathcote in central Victoria was surveyed for road-killed macropods over 5 years. Road-kills of seven swamp wallabies, and 37 eastern grey kangaroos were recorded. Kills of grey kangaroos peaked in the autumn of two years. The majority of kills were adult males, indicating that motor vehicles act as a selective mortality factor. Most road-kills also occurred around the time of full moon, suggesting that kangaroos are more mobile during that phase. The highest incidence of kills per kilometer was recorded between an area of woodland on one side of the road and farmland on the other. Kangaroo warning signs were erected during the study but were not effective in reducing the incidence of road-kills.

Coulson, G. 1989. The effect of drought on road mortality of macropods. Australian Wildlife Research. 16: 79-83.

Coulson, R. 1996. Method for measuring vehicle noise source heights and subsource spectra. Transportation Research Record. 1559: 8-13.

Cristoffer, Cris. 1991. Road mortalities of northern Florida vertebrates. Fla. Sci. 54(2): 65-68.

Cristol, Daniel A.; Switzer, Paul V.; Johnson, Kara L.; Walke, Leah S. 1997. Crows do not use automobiles as nutcrackers: putting an anecdote to the test. Auk. 114(2): 296-298.
The authors refute the belief that crows use automobiles to crack nuts. Extensive observations showed that crows drop nuts on roads to crack them and that cars are involved only incidentally.

Crome, F. H.; Richards, G. C. 1988. Bats and gaps: microchiropteran community structure in a Queensland rainforest. Ecology. 69: 1960-1969.

Crooks, K. R. 1994. Den-site selection in the island spotted skunk of Santa Cruz Island, California. Southwestern Naturalist. 39: 354-357.
Dens are important ecological characteristics of carnivores, yet little is known of the denning ecology of the island spotted skunk, an insular endemic subspecies whose continued existence is uncertain. Den characteristics and patterns of use were quantified for the island spotted skunk of Santa Cruz Island by

locating eight radio-collared individuals. Skunks readily excavated dens in a variety of substrates, including earth and roots beneath shrubs, cavities in rocks, open grassy areas, road cuts, human-made structures, and trunks and roots of oaks. Individual skunks used several dens distributed throughout their home ranges. Some dens were used by more than one skunk, yet only females shared dens simultaneously. Overall, skunks seemed opportunistic in their den-site selection, suggesting that dens may not be a limiting factor for island spotted skunk populations.

Cunningham, Stanley C.; Layne, Hanna; Joseph, Sacco 1993. Possible effects of the realignment of U.S. Highway 93 on movements of desert bighorns in the Black Canyon area. In: Rowlands, P. G.; van Riper, C.; Sogge, M. K., eds. Proceedings of the first biennial conference on research in Colorado Plateau National Parks; 1991 July 22-25; Flagstaff, AZ. Phoenix, AZ: U.S. National Park Service: 83-100.

Curatolo, J. 1983. Caribou response to the pipeline/road complex in the Kuparuk oilfield, Alaska. Proceedings of the Alaska Science Conference. 34: 10-13.

Curatolo, J. A.; Murphy, S. M. 1986. The effects of pipelines, roads, and traffic on the movements of caribou (*Rangifer tarandus*). Canadian Field Naturalist. 100: 218-224.

Dalton, L. B.; Stanger, M. C. 1990. Reflector effects on deer road kills. Price, UT: Utah Division of Wildlife Resources. 9 p.

Damas. 1983. Wildlife mortality in transportation corridors in Canada's national parks. Impact and mitigation. Ottawa, Ontario: Parks Canada. [Pages unknown].

Daniels, R. J. R. 1994. A landscape approach to conservation of birds. Journal of Biosciences. 19(4): 503-509. Landscape ecology as a discipline in science is rather young. However its principles appear promising in outlining conservation strategies including a wide range of organisms, particularly birds. Birds due to their mobility use a variety of environmental resources, especially habitats. However, currently these habitats are only available in patches over most of the tropical world. Further whatever is left is under constant human pressure. This paper, therefore, addresses this problem and suggests means of dealing with it using the landscape approach as outlined by landscape ecology. The landscape approach starts with the realization that patches of habitats are open and interact with one another. Corridors of trees along roads, hedgerows and canals in a landscape can aid in the movement of species. Hence the landscape approach considers patches of habitats as interacting elements in the large matrix of the landscape. The landscape approach also integrates concepts. It puts together often debated issues such as whether to preserve maximum species diversity, to maximize representativeness, or to preserve only the valuable species. Based on a case study of the Uttara Kannada district in Karnataka, these oft-opposing views and complications can be dealt with practically and synthesized into a conservation strategy far the diverse avifauna of the Western Chats.

Darrall, N. M. 1987. Environmental concerns in rights-of-way management in Europe. In: Byrnes, W. R.; Holt, H. A., eds. Proceedings of the fourth symposium on environmental concerns in rights-of-way management. 587-591.

Dau, J. R.; Cameron, R. D. 1986. Effects of a road system on caribou distribution during calving. Rangifer. Special Issue(1): 95-101.

Davey, Stuart P. 1974. Off-road vehicles: on or off the public lands. Transactions of the North American Wildlife Natural Resource Conference. 39: 367-375.

David, L. M.; Warner, R. E. 1981. Roadside management for pheasants and songbirds in east-central Illinois. In: Tillman, R. E., ed. Proceedings of the second symposium on environmental concerns in rights-of-way management; 1979 October 16-18; Ann Arbor, MI. Ann Arbor: University of Michigan: 63.1-63.8.

Davis, A. E. 1975. Death on the highway. British Columbia Outdoors. February: 29-31.

Davis, J. M.; Roper, T. J.; Shepherdson, D. J. 1987. Seasonal distribution of road kills in the European badger (*Meles meles*). Journal of Zoology. 211: 525-529.

Davis, P. B.; Humphrys, C. R. 1977. Ecological effects of highway construction upon Michigan woodlots and wetlands. Summary of study findings phase 1 report. East Lansing: Michigan State University, Agricultural Experiment Station; FHWA/MI-7797417. 72 p.
To determine the ecological effects of highway construction and use upon Michigan woodlots and wetlands, ten sites located along a 45-mile segment of I-75 between Roscommon and West Branch were studied. These sites were examined in respect to several natural science parameters: soils, hydrology, water quality, forestry, and wildlife. The study provided an evaluation of the environmental impact of highway construction and use on the parameters measured by each research discipline. Several models for determining optimum highway location were also evaluated including the University of Georgia model, which was modified and tested for use by the Michigan Department of State Highways and Transportation. This summary consists of extracts of a brief and pertinent nature from the individual reports written by the investigating team for each research discipline. Methodologies utilized, site descriptions, environmental impacts, conclusions and recommendations are detailed.

Davis, W. H. 1934. The automobile as a destroyer of life. Science. 79: 504-505.

Davison, A. W. 1971. The effects of de-icing salt on roadside verges. Journal of Applied Ecology. 8: 555-561.

Dawson, B. L. 1991. South African road reserves: valuable conservation areas? In: Saunders, D. A.; Hobbs, R. J., eds. Nature conservation 2: the role of corridors. Chipping Norton, Australia: Surrey Beatty and Sons: 119-130.

de-la-Cruz-Aleman, M. A. 1992. Provisional report of the mortality of vertebrates on the roads of Toledo, September 1991. In: Lopez, Redondo, ed. I jornadas para el estudio y prevencion de la mortalidad de vertebrados en carreteras, Madrid, 5 y 6 de Octubre de 1991. Tomo 2. [Sessions in the study of prevention of road mortalities of vertebrates, Madrid, 5 and 6 October, 1991. Volume 2.]. Ambiental, Madrid: Coordinadora de Organizacciones de Defensa: 123-126.

DeCalesta, D. S. 1990. Factors influencing number of road-killed deer in Pennsylvania. Journal of the Pennsylvania Academy of Science. 63(1-3): 210-213.

Decker, D. 1987. A limited survey of road kills on the Warsaw-Hamilton blacktop. Illinois Birds Birding. 3(3): 63-64.

Degn, H. J. 1985. Road-kill of toads (*Bufo bufo*). Flora Og Fauna. 1(1): 17-21.

Del Frate, G. G.; Spraker, T. H. 1991. Moose vehicle interactions and an associated public awareness program on the Kenai Peninsula, Alaska. Alces. 27: 1-7.
Summarizes moose roadkill statistics for the Kenai Peninsula from 1977 to 1991, and discusses a public awareness program implemented to reduce vehicle moose collisions. The public awareness program appeared to be effective at reducing collisions.

Demartis, A. M. 1987. Birds killed by traffic on the roads and their density. Riv. Ital. Ornitol. 57(3-4): 193-205.

Demers, Charlotte L.; Richard, W. S. 1990. Effects of road deicing salt on chloride levels in four Adirondack streams. Water, Air, Soil Pollution. 49(3/4): 369-373.

Demers, M. N. 1993. Roadside ditches as corridors for range expansion of the western harvester ant (*Pogonomyrmex-occidentalis* Cresson). Landscape Ecology. 8(2): 93-102.
The northeasternmost range extent of the western harvester ant (*Pogonomyrmex occidentalis* Cresson) occurs just east of the Missouri River in North Dakota. The earliest known records (1882) of this species place it in the same general position as existed at the time of the first exhaustive survey in 1966. A 1990 survey reveals substantial eastward and northward range expansion beyond locations known to be stable between 1966 and 1978. This suggests that this species' range has not yet stabilized with post quaternary climatic changes. Field observations show that, near the expanding edge of its range, a strong relationship exists between anthropogenic modification of the landscape and locational propensity. Specifically, land uses which periodically disrupt the soil, such as row cropping, show a nearly absolute lack of occupancy, while the well-drained, sheltered roadside ditches are heavily populated by *P. occidentalis*. The roads themselves closely resemble bare-soil, post-nuptial landing sites known to encourage *P. occidentalis* ant colonization. This strongly suggests that the roadside ditches act as corridors for range expansion of the species. The similarity between road network density within and beyond the species range, combined with severe drought conditions during 1988 and 1989 indicate that climate, as a regional scale variable, is the stimulus for range expansion, while landscape level queues provided by the roadside ditches, are the mechanism by which it is accomplished. Of the site level factors examined, only roadside ditch azimuths and soil texture showed statistical significance as possible locational factors, but no causal mechanism can be assumed.

Den Boer, P. J. 1979. The significance of dispersal power for the survival of species, with special reference to the carabid beetles in a cultivated countryside. Fortschr. Zool. 25: 79-94.

Dennis, R. L. 1986. Motorways and cross-movements. An insect "mental map" of the M56 in Cheshire. Bulletin of the Amateur Entomologist Society. 45: 228-243.

Denny, M. 1994. High bird mortality as a result of painted lady butterfly migration in eastern Oregon, spring 1992. OREGON BIRDS. 0(1):23.

DeSanto, R. S.; Smith, D. G. 1993. An introduction to issues of habitat fragmentation relative to transportation corridors with special reference to high speed rail. Environmental Management. 17(1): 111-114.
A review of fragmentation and habitat loss impacts of transportation development. They note that rail corridors are narrower and produce less runoff, so they may have less of an impact. Some mitigation measures also are reviewed.

Desire, G.; Recorbet, B. 1987. Protection de la grande faune: experimentation de reflecteurs en foret d'Olonne, Vendee - Trois annees de suivi. In: Bernard, J. M.; Dansirat, M.; Kempf, C.; Tille, M., eds. Routes et faune sauvage: actes du colloque. Strasbourg: Conseil de l'Europe: 339-345.

DesJardins, C. R. 1979. Ecological mitigation: a viable option in the Federal-Aid Highway Program. Gen. Tech. Rep. GTR-RM-65. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Range and Experiment Station. 565 p.

Devos, A. 1949. Timber wolves killed by cars on Ontario highways. Journal of Mammalogy. 30:[Pages unknown].

Dexel, R. 1989. Investigations into the protection of migrant amphibians from the threats from road traffic in the Federal Republic of Germany - a summary. In: Langton, T. E. S., ed. Amphibians and roads. Proceedings of the toad tunnel conference; 1989 January 7-8; Rendsburg, Federal Republic of Germany. Shefford, England: ACO Polymer Products Ltd.: 43-49.

Dhindsa, M. S.; Sandhu, J. S.; Toor, H. S. 1988. Roadside birds in Punjab (India): relation to mortality from vehicles. Environmental Conservation. 15: 303-310.

Dickerson, L. M. 1939. The problem of wildlife destruction by automobile traffic. Journal of Wildlife Management. 3: 104-116.

Dickson, R. C.; Dickson, A. P. 1993. Kestrels feeding on road casualties. Scottish Birds. 17(1):56.

Dietz, D. R.; Tigner, J. R. 1968. Evaluation of two mammal repellents applied to browse species in the Black Hills. Journal of Wildlife Management. 32: 109-114.

Dillon, Ltd. 1993. Literature review of wildlife/vehicle collisions and Highway 24 deer/vehicle accident analysis. Ontario, Canada: Ontario Ministry of Transportation. [Pages unknown].

Disney, H. J.; Fullagar, P. J. 1978. A note on road kills. Corella. 2(5): 89-90.

Disney, M.; Spiegel, L. K. 1992. Sources and rates of San Joaquin kit fox mortality in western Kern County, California. Transactions of the Western Section of the Wildlife Society. 28: 73-82.

Dixon, N.; Shawyer, C.; Sperring, C. 1996. The impact of road mortality on barn owl populations: its significance to road development schemes. Raptor. 23: 37-40.
Tyto alba in England.

Doak, D. F.; Marino, P. C.; Kreiva, P. M. 1992. Spatial scale mediates the influence of habitat fragmentation on dispersal success: implications for conservation. Theoretical Population Biology. 41: 315-336.
In analysis of simulated landscapes with stochastically clustered habitat fragments they found that the scale of clustering is the most important feature in determining disperser performance. They make a call for more explicit consideration of scale concerns in field studies.

Doan, K. H. 1970. Effects of snowmobiles on fish and wildlife resources. International Association of Game Fish Conservation. 60: 97-103.

Dodd, C. K.; Enger, K. M.; Stuart, J. N. 1989. Reptiles on highways in north-central Alabama, USA. Journal of Herpetology. 23: 197-200.

Dodds, P. J.; Maurer, M. 1996. Wildlife habitat evaluation/upland mitigation: the PennDOT perspective. In: Evink, G.; Ziegler, D.; Garrett, P.; Berry, J. , eds. Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors: Proceedings of the Florida Department of Transportation/Federal Highway Administration transportation-related wildlife mortality seminar; 1996 April 30-May 2; Orlando, FL. FHWA-PD-96-041. Washington, DC: U.S. Department of Transportation, Federal Highway Administration: 235-259.
Overview of PennDOT's wildlife habitat assessment and upland mitigation strategies.

Donazar, J. A.; Hiraldo, F.; Bustamante, J. 1993. Factors influencing nest site selection, breeding density and breeding success in the bearded vulture (*Gypaetus barbatus*). Journal of Applied Ecology. 30(3): 504-514.
We examined the nest site selection, breeding density and breeding success in the bearded vulture *Gypaetus barbatus* in relation to physiography, climate, land-use and degree of human disturbance. The study area was in the Pyrenean Cordillera, Spain, where the largest European population of this species occurs. Univariate analyses and Generalized Linear Models were employed. Models correctly classified the 78% of the cliffs analysed (occupied by bearded vultures, and selected at random). The probability of occupation of a cliff by bearded vultures was directly related to the ruggedness of the topography, altitude, distance to the nearest bearded vulture occupied nest, and distance to the nearest village. Breeding density was positively correlated with altitude and ruggedness of the topography and negatively correlated with snow precipitation. Open areas seemed also to have positive effects, probably by increasing the availability of food, although its effects were not separable from that of the relief, as the two factors covary. Bearded vultures showed lower breeding success in areas with high

potential human disturbance (density of paved roads). The existence of abrupt and open lands might have a positive effect on breeding success by reducing accessibility to humans, and perhaps by increasing food availability.

Doncaster, C. P.; Micol, Thierry; Jensen, Susanne P. 1996. Determining minimum habitat requirements in theory and practice. Oikos. 75(2): 335-339.
Erinaceus europaeus in England.

Douglass, R. J. 1977. Effects of winter road on small mammals. Journal of Applied Ecology. 14(3): 827-834.

Douglass, R. J.; Ernst, J. 1986. Impacts of vehicle traffic on coyote movement in western Colorado. In: Comer, R. D., ed. Issues and technology in the management of impacted western wildlife: Proceedings of a national symposium; 1985 February 4-6; Glenwood Springs, CO. Boulder, CO: Thorne Ecological Institute: 296-300.

Dovers, S. R.; Norton, T. W. 1994. Toward an ecological framework for sustainability: considerations for ecosystem management. Pacific Conservation Biology.(4): 283-293.

Dowler, R. C.; Swanson, G. A. 1982. High mortality of cedar waxwings associated with highway plantings. Wilson Bulletin. 94: 602-603.
Cited in Forman 1995 as an example of attractant and mortality.

Downes, Sharon J.; Asyde, Kathrine A.; Elgar, Mark A. 1997. The use of corridors by mammals in fragmented Australian eucalypt forests. Conservation Biology. 11(3): 718-726.
The authors investigated the abundance and diversity of mammal populations in remnant forest, pasture, and roadside corridors in Victoria, Australia. Data suggest that corridors can provide useful habitat for mammalian communities but provision of corridors may not solve the problem of continued habitat fragmentation.

Drews, C. 1995. Road kills of animals by public traffic in Mikumi National Park, Tanzania, with notes on baboon mortality. African Journal of Ecology. 33: 89-100.
The Tanzania-Zambia highway crosses Mikumi National Park over a stretch of 50 kilometers. The road was rehabilitated between May 1990 and November 1991 resulting in higher average driving speeds. Data were collected on the incidence of road kills of animals within the park boundaries during this period. The list of 183 mammals, birds and reptiles killed by vehicles included at least 52 species, two of which are endangered: the African elephant (*Loxodonta africana* Blumenbach) and the African hunting dog (*Lycaon pictus* Temminck). The road-kill rate increased and was estimated at a minimum of three road kills per day (21.8 road kills/km/yr) by the end of the study. Road kills were more frequent near water holes and traditionally used animal tracks. The demographic effect of road kills on troops of yellow baboons (*Papio cynocephalus* Linnaeus), which include the highway in their ranges, is in the order of 10% of the total yearly losses. High speed and the danger of collisions with wildlife are causing regular accidents in Mikumi National Park. Adequate signposts along the road and speed bumps are recommended in order to reduce the average driving speeds for the sake of humans and wildlife.

Dreyer, W. A. 1935. The question of wildlife destruction by the automobile. Science. 82: 439-440.

Driessen, M. M.; Mallick, S. A.; Hocking, G. J. 1996. Habitat of the eastern barred bandicoot, *Perameles gunnii*, in Tasmania: an analysis of road-kills. Wildlife Research. 23: 721-727.
The habitat requirements of the eastern barred bandicoot, *Perameles gunnii*, in Tasmania were investigated with road-kill survey data and by mapping habitat features along survey routes. Road-kills of eastern barred bandicoots were most numerous in the southeast and northwest, less common in the northeast and midlands, and very uncommon on the east coast. Logistic regression of bandicoot presence/absence data suggested that traffic volume is the major determinant of the road-kill distribution of eastern barred bandicoots around Tasmania. Along with traffic volume, rainfall was

found to be strongly associated with the presence of eastern barred bandicoot road-kills for the state combined and for the southeast and northeast, while along the Huon Highway in the South-east, soil depth was associated with the presence of roadkills. Favoured habitat of the eastern barred bandicoot is high-quality agricultural land with deep soils and high rainfall. It is hypothesised that clearing for agriculture in southeastern, northeastern and northwestern Tasmania has opened up previously unsuitable, heavily forested habitat for colonisation by eastern barred bandicoots. The resulting mosaic of pasture and remnant bush appears to provide ideal habitat for the eastern barred bandicoot. However, the majority of bandicoot habitat is found on private land, making the species vulnerable to changes in farming practices. Possible management options are briefly discussed.

Drummond, F. 1989. Factors influencing road mortality of Key deer. Carbondale, IL: Southern Illinois University. 84 p. M.S. thesis.

Dufty, A. C. 1994. Population demography of the eastern barred bandicoot (*Perameles gunnii*) at Hamilton, Victoria. Wildlife Research. 21: 445-457.
Totals of 32 female and 53 male *Perameles gunnii* were caught 241 and 330 times, respectively, during 4,340 trap-nights at Hamilton, Victoria. Residents comprised 75.3% (n = 64) of the sample. Morphometric comparison indicates that *P. gunnii* is sexually dimorphic. Sex ratios (expressed in percentage of females) of 55% (dependent juvenile), 45% (independent juvenile) and 37.9% (adult) were determined. The age structure of the live-trapped population changed substantially between July 1989 (42.9% juvenile, 9.5% subadult and 47.6% adult) and August 1990 (46.2% juvenile, 15.4% subadult and 34.6% adult). The mean age of captured female bandicoots increased during the study, from 9.8 months in July 1989 to 15.8 months in August 1990. In all, 24 of 32 females produced 145 pouch young in 66 litters, with a mean (+- s.e.) litter size of 2.2 +- 0.1 (n = 66). The number of females that were lactating each month was high throughout the study (85%) and peaked during spring and autumn when all captured females were lactating. Sexual maturity for males and females occurred at about 5 and 3.5 months of age, respectively. The causes of mortality of *P. gunnii* between 1980 and 1990 included road death (63%, n = 85), cat predation (17.8%, n = 24), disease (8.1%, n = 11), trap death (5.2%, n = 7), machinery (3.7%, n = 5) and dog predation (2.2%, n = 3). A total of 25 *P. gunnii* died from unknown causes. Cat predation of *P. gunnii* may be high amongst juveniles and subadults but low for adults. A net emigration rate of 18% of individuals known to be alive indicates that the Hamilton Municipal Tip is a source for dispersal to other subpopulations. The 1990 distribution of the population was about 169 ha, within the City of Hamilton and adjacent Shire of Dundas, Victoria. There has been a decline in distribution and some local extinctions of *P. gunnii* in several areas between 1988 and 1990.

Dunforth, A. A.; Errington, F. P. 1964. Casualties among birds along a selected road in Wiltshire. Bird Study. 11: 168-182.

Eason, G. W., Jr.; Fauth, J. E. 1996. Patterns of diversity: the influence of roads and firebreaks on the declining amphibian population. Bulletin of the South Carolina Academy of Science. 58: 90-94.

Eckstein, Ronald G.; O'Brien, Thomas F.; Rongstad, Orrin J.; Bollinger, John G. 1979. Snowmobile effects on movements of white-tailed deer: a case-study. Environmental Conservation. 6(1): 45-51.

Edwards, R. W.; Slater, F. M. 1981. Impact of road deaths on wildlife conservation. Nat Wales. 17: 153-156.

Engel, E.; Bressanutti, C. 1993. Functionality of a new protection site for amphibians in the Kehlen township. Bulletin De La Societe Des Naturalistes Luxembourgeois. 1993: 121-127.
During the period of March/April 1992 the migration of amphibians was studied in the area of the new built protection site for amphibians crossing the road near Kehlen. Therefore the tunnels were closed by pails to catch and count the crossing amphibians and test the acceptance of the new system. Four species were recorded, mainly *Bufo bufo*. The study shows that the tunnel system was used by the studied species to cross the road and there was a very low level of mortality rate of amphibians on the road.

Environmental, Resources M. 1996. The significance of secondary effects from roads and road transport on nature conservation. English Nature Research Report No.178.

Erickson, P. A.; Camougis, G.; Robbins, E. J. 1978. Highways and ecology: impact assessment and mitigation. Worchester, MA: New England Research, Inc.; FHWA/RWE/OEP78/2. 199 p. Sponsored by: Federal Highway Administration, Office of Environmental Policy, Washington, DC.
The enactment of the National Environmental Policy Act 1969 (NEPA) expanded the requirements for the highway professional to consider all aspects of a highway development project. Part of this assessment is the effects of highway projects, highway operations, and highway maintenance on natural resources. These effects occur at both the biological and ecological level. This book uses an ecosystem approach to impact assessments. The components and dynamics of terrestrial, aquatic and wetland ecosystem are described. Potential biological and ecological impacts of a highway project are also described. This analysis is broken down into pre-design, design, construction and operation and maintenance phases. Extensive discussions on methods of mitigating adverse impacts and enhancing the existing biological resources are included.

Ericson, James E. 1983. Aerial photo censusing of sandhill cranes: distributional effects of Interstate 80. Proceedings of the North Dakota Academy of Science. 37: 105-108.

Estrada, J.; Riera, X. 1996. High mortality of *Hirundinidae* on roads in and around the Ebro Delta in spring 1992. Butlleti Del Grup Catala D'anellament. 2: 17-22.

Evenden, F. G. 1971. Animal road kills. Atl. Nat. 26: 36-37.

Evink, G. L. 1996. Florida Department of Transportation initiatives related to wildlife mortality. Orlando, FL: Florida Department of Transportation. [Pages unknown].; Report from the Environmental Management Office.

Evink, G. L.; Ziegler, D.; Garrett, P.; Berry, J., eds. 1996. Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors: Proceedings of the Florida Department of Transportation/Federal Highway Administration Transportation-related wildlife mortality seminar; 1996 April 30-May 2; Orlando, FL. FHWA-PD-96-041. Washington, DC: U.S. Department of Transportation, Federal Highway Administration. 336 p.

Evink, G. 1998. Ecological highways. In: Evink, G. L.; Garrett, P.; Zeigler, D.; Berry, J., eds. Proceedings of the international conference on wildlife ecology and transportation; 1998 February 10-12; Ft. Myers, FL. Tallahassee, FL: Florida Department of Transportation: 253-257.
This paper presents a model for planning, development, construction, and roadside management which looks at both the floral and faunal aspects of the highway for designation of the appropriate highways as ecological highways. This designation would be similar to the existing scenic highways designation but concentrates on the natural resource values associated with the highways. The designation would only be used in areas where adjacent land management was directed toward natural resource management for wildlife. These would be areas with large public land holdings unless agreements for long-term management of private lands could be arranged. The designation would require a management plan similar to those developed for scenic highways. The management plan would include features of management and structure that would be needed along the corridor in order to qualify for the designation. The principles supported by this concept would include early planning, management of flora and fauna in a manner similar to that of adjacent natural habitat, habitat connectivity for wildlife movement, the use of native species, and letting natural processes dictate management in all but a clear recovery zone. The purpose would be to provide the responsible transportation agency with guidance on how to manage a given area to support the natural values of the area while accommodating safety for both the motorists and wildlife of the area. Attention would be given to the micro- and macro-scale aspects of the relation of the highway roadside to the larger adjacent environments in the development of a management plan The management plan would

identify the highway, length of the highway to be designated, the natural values of the area which justify the designation, and the future features and management that would be necessary. If future highway capacity improvements prove necessary, the measures to make such improvement possible would be identified in the management plan - wildlife crossings, fencing, signing, speed limit reduction, and vegetation management.

Evink, G. 1998. 1998 international conference: wildlife ecology and transportation. Wrap-up session: recommendations for the future. In: Evink, G. L.; Garrett, P.; Zeigler, D.; Berry, J., eds. Proceedings of the international conference on wildlife ecology and transportation; 1998 February 10-12; Ft. Myers, FL. Tallahassee, FL: Florida Department of Transportation: 258-259.
This paper summarized the findings and recommendations from panels and audience input on the conservation and management of rare wildlife, fish, and plant resources located on federal lands that are affected by highways. Recommendations are included on policy, coordination, development of a handbook, development of standards and guides, training, and greater understanding of the issues.

Fahrig, L.; Merriam, G. 1985. Habitat patch connectivity and population survival. Ecology. 66: 1762-1768.
We constructed a patch dynamics model which can be used to simulate the changing sizes of resident populations in a series of interconnected habitat patches. We applied the model to white-footed mice inhabiting patches of forest in an agricultural landscape. The model predicts that mouse populations in isolated woodlots have lower growth rates and are thus more prone to extinction than those in connected woodlots. Field data support this prediction.

Fahrig, L.; Pedlar, J. H.; Pope, S. E. and others. 1995. Effect of road traffic on amphibian density. Biological Conservation. 73(3): 177-182.
We studied the effect of traffic intensity on local abundance of anurans. We counted dead and live frogs and toads per kilometer and estimated frog and toad local abundances using breeding chorus intensities on similar roads through similar habitats, but with different levels of traffic intensity. After correcting for effects of date, local habitat, time, and region, our analyses demonstrated that (I) the number of dead and live frogs and toads per kilometer decreased with increasing traffic intensity; (2) the proportion of frogs and toads dead increased with increasing traffic intensity; and (3) the frog and toad density, as measured by the chorus intensity, decreased with increasing traffic intensity. Taken together, our results indicate that traffic mortality has a significant negative effect on the local density of anurans. Our results suggest that recent increases in traffic volumes worldwide are probably contributing to declines in amphibian populations, particularly in populated areas.

Falk, N. W. 1975. Fencing as a deterrent to deer movement along highways. University Park, PA: Pennsylvania State University. [Pages unknown]. Ph.D. dissertation.

Falk, N. W.; Graves, H. B.; Bellis, E. D. 1978. Highway right-of-way fences as deer deterrents. Journal of Wildlife Management. 42: 646-650.
This study evaluated the effectiveness of 2.26 meter high fences in keeping deer off rights-of-way along I-80 in a wooded area of Pennsylvania. Properly repaired fences served as effective barriers to deer. Deer fences are not useful in areas of high traffic density because the frequency of vehicle passage reduces deer crossing behavior.

Farquharson, E. 1986. Ring roads and badgers. Edinburgh Natural History Society Journal. 1986: 21-22.

Fearnside, Philip M.; Gabriel de Lima Ferreira. 1984. Roads in Rondonia: highway construction and the farce of unprotected reserves in Brazil's Amazonian forest. Environmental Conservation. 11(4): 358-360.

Fehlberg, U. 1994. Ecological barrier effects of motorways on mammalian wildlife - an animal protection problem. Deutsche Tierarztliche Wochenschrift. 101(3): 125-129.
In the course of May 1992 to April 1993, ecological barrier effects to the Hanover-Berlin Autobahn (Germany) on mammalian wildlife were investigated. In this period 1566 carcasses of various species

were found on the road. Traffic volume showed an increase of 600% from 1989 (15,000 cars/24 hr) to 1992 (90,000 cars/24 hr). Wildlife use of 13 highway underpasses was monitored by video camera and countline checkpoints. Though they had various dimensions nearly all underpasses investigated were used by mammalians at least by fox, rabbit or marten. Because of the knowledge of the locations both of the maxima points of road mortality of wildlife and their use of controlled underpasses one is able to give recommendations for optimal localisations and dimensions of buildings which makes the wildlife able to pass the traffic line. The investigation proofs that the amount of wildlife killed on roads in Germany has been underestimated about 2000%.The problem of "just" wounded but not instantly killed animals while having an accident is pointed out as a severe problem from the animal welfare's point of view.

Feldhammer, G.; Gates, J.; Harman, D. and others. 1986. Effects of interstate highway fencing on white-tailed deer activity. Journal of Wildlife Management. 50(3): 497-503.
Locations of white-tailed deer along a 41.4-kilometer section of I-84 in Pennsylvania were determined by radio telemetry and spotlight surveys. Bucks crossed roads more often ($P<0.05$) than does. Two of 22 radio-collared deer were killed by vehicles during the study period. Hourly telemetry fixes showed that deer movements were not oriented in any general pattern relative to a highway. During 36 spotlight surveys, 2045 deer sightings were made, of which 1,687 were on the I-84 right-of-way. More deer were on the right-of-way in fall than summer. Most of the 100 road-kills recorded during the study occurred in fall and winter. A 2.7 meter fence reduced the number of deer on the right-of-way compared to an alternative 2.2 meter fence, but it was not effective in reducing the number of road-kills. There was no significant relationship ($P>0.05$) between road-kills and highway direction, habitat, topography, or fence placement. However, deer were killed more often within 0.48 kilometers of an interchange. Management efforts to reduce the incidence of road-killed deer should address increasing the effectiveness of deer fence and decreasing the incentive for deer to enter the right-of-way.

Feldmann, R.; Geiger, A. 1989. Protection for amphibians on roads in Nordrhein-Westphalia. In: Langton, T. E. S., ed. Amphibians and roads. Proceedings of the toad tunnel conference; 1989 January 7-8; Rendsburg, Federal Republic of Germany. Shefford, England: ACO Polymer Products Ltd.: 51-57.

Ferrer, M.; Harte, M. 1997. Habitat selection by immature Spanish imperial eagles during the dispersal period. Journal of Applied Ecology. 34(6): 1359-1364.
The Spanish imperial eagle *Aquila adalberti* is the most endangered bird of prey in Europe, with less than 150 pairs remaining alive, and it is one of the most endangered species in the world. The densest Spanish imperial eagle population is located in the Donana National Park, south-western Spain and is made up of 15 to 16 breeding pairs. Since 1973, a variety of management techniques have been implemented to increase productivity in the breeding population. Despite this, eagles have not colonized the surrounding area. Studies were carried out to provide a quantitative description of the habitats selected by immature Spanish imperial eagles during their dispersal period. The exact locations of the 23 temporary settling areas were determined by radio-tracking from the ground and periodic checks by light aircraft. To evaluate available but unused habitats, coordinates of the same number of random points were generated and compared to actual locations. The results indicated that young eagles select areas with pasture or cultivated farmland covered by scattered *Quercus* spp. trees (Oak savanna) and avoid irrigated fields and paved roads. The ecological data provided by this study can be used to predict those areas where changing land use would have the greatest, and least effects on dispersing eagles and, in consequence, on the stability of the breeding population. Management recommendations for those areas include modification of power lines to avoid electrocution during the dispersal phase, presumption against construction of new power lines or roads, presumption against any increase in tree plantations, and financial incentives to maintain existing management regimes in preferred areas, i.e., non-irrigated fields, pastures and cultivated farmland with a scattered distribution of *Quercus* spp. and *Olea* spp.

Ferris, C. R. 1974. Effects of highways on red-tailed hawks and sparrow hawks. Morgantown: West Virginia University. [Pages unknown]. M.S. thesis.

Ferris, C. R. 1977. Effects of interstate 95 on songbirds and white-tailed deer in northern Maine. Orono, ME: University of Maine. [Pages unknown]. M.S. thesis.

Ferris, C. R.; Palman, D. S.; Richens, V. B. 1978. Ecological impact of Interstate 95 on birds and mammals in northern Maine, interim report 1975-77. Bangor, ME: Maine Department of Transportation, Materials Research Division; Tech. Rep. 77-12. 129 p.

Ferris, C. R. 1979. Effects of Interstate 95 on breeding birds in northern Maine. Journal of Wildlife Management. 43: 421-427.

Findlay, C. S.; Houlahan, J. 1997. Anthropogenic correlates of species richness in southeastern Ontario wetlands. Conservation Biology. 11(4): 1000-1009.
We examined the relationship between the richness of four different wetland taxa (birds, mammals, herptiles, and plants) in 30 southeastern Ontario, Canada wetlands and two anthropogenic factors: road construction and forest removal/conversion on adjacent lands. Data were obtained from two sources: road densities and forest cover from 1:50,000 Government of Canada topographic maps and species lists and wetland areas from Ontario Ministry of Natural Resources wetland evaluation reports. Multiple regression analysis was used to model the relationships between species richness and wetland area, road density, and forest cover. Our results show a strong positive relationship between wetland area and species richness for all taxa. The species richness of all taxa except mammals was negatively correlated with the density of paved roads on lands up to 2 kilometers from the wetland. Furthermore, both herptile and mammal species richness showed a strong positive correlation with the proportion of forest cover on lands within 2 kilometers. These results provide evidence that at the landscape level, road construction and forest removal on adjacent lands pose significant risks to wetland biodiversity. Furthermore, they suggest that most existing wetland policies, which focus almost exclusively on activities within the wetland itself and/or a narrow buffer zone around the wetland perimeter, are unlikely to provide adequate protection for wetland biodiversity.

Finnis, R. G. 1960. Road casualties among birds. Bird Study. 7: 21-32.

Flaa, J. 1989. Trans-Canada Highway: phase IIIB wildlife study. Banff, AB: Banff National Park Warden Service 45 p.

Florida Department of Transportation. 1992. Report on the animal crossing study. Tallahassee, FL: Florida Department of Transportation, Environmental Management Office. [Pages unknown].

Flygare, H. 1976. Trans-Canada Highway Rocky Mountain bighorn sheep vehicle mortality. Banff, Alberta: Banff National Park; Unpublished report. [Pages unknown].

Flygare, H. 1977. Wildlife mortality study, Trans-Canada Highway. Progress report. Banff, Alberta: Parks Canada, Banff National Park. [Pages unknown].

Flygare, H. 1978. Section C: ungulate census in the Bow Valley corridor - winter 1976-77. Banff, Alberta: Parks Canada, Banff National Park Warden Service. [Pages unknown].

Flygare, H. 1978. Section D: ungulate foraging areas in the Bow Valley corridor. Banff, Alberta: Parks Canada, Banff National Park Warden Service. [Pages unknown].

Flygare, H. 1978. Section E: Trans-Canada Highway wildlife crossings, 1964-77. Banff, Alberta: Parks Canada, Banff National Park Warden Service. [Pages unknown].

Flygare, H. 1978. Section B: Trans-Canada Highway east gate to Banff/Yoho boundary, 1964-1977. Banff, Alberta: Parks Canada, Banff National Park Warden Service. [Pages unknown].

Flygare, H. 1978. Wildlife mortality statistics, sections A and F. Banff, Alberta: Parks Canada, Banff National Park Warden Service. [Pages unknown].

Flygare, H. 1978. Wildlife mortality statistics, Trans-Canada Highway. Banff, Alberta: Parks Canada, Banff National Park Warden Service. [Pages unknown].

Flygare, H. 1979. Section F, highway-wildlife relationships: an annotated bibliography. Banff, Alberta: Parks Canada, Banff National Park Warden Service. [Pages unknown].

Flygare, H. 1979. Ungulate mortality and mitigated measures - Trans-Canada Highway, Banff National Park. Banff, Alberta: Parks Canada, Banff National Park Warden Service. [Pages unknown].

Foppen, R.; Reijnen, R. 1994. The effects of car traffic on breeding bird populations in woodland. II. Breeding dispersal of male willow warblers (*Phylloscopus trochilus*) in relation to the proximity of a highway. Journal of Applied Ecology. 31: 95-101.
In this study the dispersal activity of male willow warblers (*Phylloscopus trochilus*) breeding next to a highway carrying heavy traffic was investigated. Breeding dispersal distances of yearling males along the road were larger than at further distances and were in the same order of magnitude as natal dispersal distances (medians being 303 and 515 meters, respectively). A simulation of dispersal directions, adjusted for actual landscape features, indicated that breeding dispersal was actively directed away from the road. There appeared to be a relation between dispersal and breeding performance for yearling males, unsuccessful males moving more frequently and further (median 294 meters) than successful males (median 120 meters). At the individual level, the increased dispersal activity of yearlings close to the highway constitutes an 'escape' mechanism from low quality areas. At the population level it possibly stabilizes source populations. Dispersal characteristics should be incorporated into spatial population models.

Forbes, B. C. 1992. Tundra disturbance studies, I: long-term effects of vehicles on species richness and biomass. Environmental Conservation. 19: 48-58.

Ford, S. G. 1980. Evaluation of highway deer kill mitigation on SIE/LAS-395 (1976-1979). Washington, DC: U.S. Department of Transportation, Federal Highway Administration; FHWA/CA/TP-80-01. 45 p.

Ford, S. G.; Villa, S. L. 1993. Reflector use and the effect they have on the number of mule deer killed on California highways. Sacramento, CA: California State Department of Transportation; FHWA/CA/PD-94/01. 12 p.
The 'Swareflex' wildlife warning system was tested to determine if it would reduce the number of mule deer killed on the highway. The test area was located on a four-mile section of State Route 36 east of Chester in Plumas County, California. This section of highway was chosen due to a history of extremely high deer kill. After three seasons, it has been determined there is no statistical difference in the mean of the deer killed when the reflectors were in operation and when they were not operating.

Forman, R. T. 1991. Landscape corridors: from theoretical foundations to public policy. In: Saunders, D. A.; Hobbs, R. J., eds. Nature conservation 2: the role of corridors. Chipping Norton, Australia: Surrey Beatty and Sons: 71-84.

Forman, R. T. 1995. Land mosaics: the ecology of landscapes and regions. Cambridge, MA: Cambridge University Press. 632 p.

Forman, R. T.; Hersperger, A. M. 1996. Road ecology and road density in different landscapes, with international planning and mitigation solutions. In: Evink, G.; Ziegler, D.; Garrett, P.; Berry, J., eds. Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors: Proceedings of the Florida Department of Transportation/Federal Highway Administration

transportation-related wildlife mortality seminar; 1996 April 30-May 2; Orlando, FL. FHWA-PD-96-041. Washington, DC: U.S. Department of Administration, Federal Highway Administration: 1-23.
Understanding and solutions for road effects depend on the spatial structure and major ecological flows across the landscape. A central question is how roads alter the landscape functions, as well as the spatial pattern. Key road-related issues in 1) suburban landscapes--loss and fragmentation of natural vegetation (direct)--barrier to species movement--loss of habitat due to avoidance of adjacent areas--loss of habitat value due to intrusive effects (e.g., noise); 2) open landscapes--fragmentation of natural vegetation strips and disruption of animal movement routes--roadkill--increased human development--exotic species invasions--pollution, 3) forested landscapes--reductions in wildlife populations--disruption of natural flows (e.g., water, fire)--introduced exotics--erosion and water quality. Effects of roads are different in different landscapes. Planning framework for addressing conflicts 1) map network of natural patterns and processes (patches and corridors); 2) superimpose road network - locations where the two cross are potential bottlenecks; and 3) identify techniques for avoiding or minimizing impacts. Mitigation techniques are amphibian tunnels, culverts for mid-sized animals, faunal under/overpasses, and landscape connectors (>100 m wide).

Forman, R. T.; Collinge, S. K. 1996. The spatial solution to conserving biodiversity in landscapes and regions. In: DeGraff, R. M.; Miller, R. I., eds. Conservation of faunal diversity in forested landscapes. London: Chapman and Hall: 537-568.

Forman, R. T.; Deblinger, R. D. 1998. The ecological road-effect zone for transportation planning and Massachusetts highway example. In: Evink, G. L.; Garrett, P.; Zeigler, D.; Berry, J., eds. Proceedings of the international conference on wildlife ecology and transportation; 1998 February 10-12; Ft. Myers, FL. Tallahassee, FL: Florida Department of Transportation: 78-96.
Ecological flows and biological diversity trace broad patterns across the landscape, whereas transportation planning traditionally focuses carefully on a narrow strip close to a road or highway. To effectively mesh the ecological dimensions with human mobility objectives the "road-effect zone," over which significant ecological effects extend outward from a road, appears to be central. The zone is many times wider than the road (with roadsides/verges), is strongly asymmetrical, and has convoluted margins. The road-effect zone is illustrated with a 24 kilometer length of a four-lane highway in the outer suburbs of Boston. The locations and distances of effects of nine processes are measured or estimated, and mapped to show the road-effect zone. Factors such as road salt affecting vegetation only extend outward meters or 10's of meters, whereas the effects of traffic noise on bird communities and the road as a barrier interrupting wildlife travel corridors extend outward 100's of meters to kilometers. Roads and roadsides cover approximately 1% of the United States, and based on calculations using scattered data, we estimate that 15 to 20% of the land is directly affected ecologically by road and vehicles. Thus the road network causes an enormous impact on America's ecological infrastructure. A vision for America's future transportation system focuses broadly on the land uses landscape ecology and the road-effect zone in transportation planning, and provides effectively for both natural processes and biodiversity, and safe and efficient human mobility.

Forys, E. A.; Humphrey, S. R. 1996. Home range and movements of the Lower Keys marsh rabbit in a highly fragmented habitat. Journal of Mammalogy. 77(4): 1042-1048.
The endangered Lower Keys marsh rabbit (*Sylvilagus palustris hefneri*) occurs in a highly fragmented habitat in the Lower Keys of Florida. A primary goal in recovering this subspecies is understanding how individuals interact in this patchy landscape. Home range and movements of marsh rabbits were studied to determine if rabbits are confined within a habitat patch (relictual population), spend most of their lives in a patch but are capable of moving between patches (metapopulation), or regularly move between habitat patches (patchy population). Radiotelemetry data were obtained from 43 rabbits representing all age and sex classes. Seven collared juvenile rabbits remained in their natal patches of habitat until the onset of sexual maturity. All of the collared subadults (five of the surviving juveniles and 12 rabbits collared as subadults) made a relatively long, one-way movement. Ten of the males moved to new patches; all but one of the females remained in their natal patches. After establishing a home range, each of the adult rabbits (12 collared as juveniles or subadults and 11 collared as adults)

remained in one patch of habitat until their deaths. These results indicate that *S. p. hefneri* exists as a metapopulation. Conservation efforts should be aimed at protecting both the rabbit's marsh habitat and the lower-mangrove and upland-forest-corridor habitats used during dispersal.

Foster, C. 1991. The effects of forest roads on hunter and wildlife distribution. Charleston: West Virginia University. [Pages unknown]. M.S. thesis.

Foster, C. C. 1985. Wild turkey research: the impact of forest roads on hunter and wildlife distributions. Charleston, WV: West Virginia Game Department; WV W-048-R-01/Job I-8. 14 p.
A study plan is presented.

Foster, M. L.; Humphrey, S. R. 1992. Effectiveness of wildlife crossings in reducing animal/auto collisions on Interstate 75, Big Cypress Swamp, Florida. Orlando, FL: Florida Department of Transportation; FL-ER-50-92. 124 p.
The Florida panther recovery plan identified a need to reduce highway mortality of panthers. To this end, a system of wildlife crossings, consisting of 24 underpasses along 40 miles of fenced highway, were installed along the newly constructed I-75 in southwest Florida. Engineering solutions to wildlife-vehicle conflicts have proven feasible under many circumstances, but most experience pertained to ungulates and small to medium-sized animals; effectiveness of crossing structures for large carnivores was not known. This study was designed to determine whether the wildlife crossings installed along I-75 effectively allow for panther movement across the road while reducing the number of panthers hit by cars.

Foster, M. L.; Humphrey, S. R. 1995. Use of highway underpasses by Florida panthers and other wildlife. Wildlife Society Bulletin. 23: 95-100.
The purpose of the study was to determine whether the combination of fencing and underpasses constructed for the upgrade of I-75 effectively allowed panther movement across the road while preventing panthers from being hit by cars. Underpasses were monitored by remote cameras and game counters. Photographs recorded 10 crossings by panthers. Other species using the underpasses included bobcats, deer, raccoons, alligators, and black bears. They infer that underpasses reduced mortality for some species, preventing the highway from becoming a demographic sink. Underpasses also reduced fragmentation of home ranges.

Fowle, S. 1996. Effects of roadkill mortality on the western painted turtle (*Chrysemys picta bellii*) in the Mission Valley, western Montana. In: Evink, G.; Ziegler, D.; Garrett, P.; Berry, J., eds. Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors: Proceedings of the Florida Department of Transportation/Federal Highway Administration transportation-related wildlife mortality seminar; 1996 April 30-May 2; Orlando, FL. FHWA-PD-96-041. Washington, DC: U.S. Department of Transportation, Federal Highway Administration: 205-223.
The author monitored turtle roadkill along 7.2 kilometers of U.S. Highway 93 from May through August, 1995 and found carcasses of 205 turtles, 43% adult males, 26% adult females, and 12% juveniles. Population density of painted turtles increased with distance from the highway.

Franchimont, J. 1993. Use by birds of roads as navigational cues. British Birds. 6(1):17.

Francis, G. R. 1978. Road transects to record the occurrence of frogs and toads in Wilmot township, Waterloo region, Southern Ontario. Ontario Field Biology. 32(1): 1-12.

Fraser, D. 1979. Sightings of moose, deer, and bears on roads in northern Ontario. Wildlife Society Bulletin. 7: 181-184.

Fraser, D.; Hristienko, H. 1982. Moose-vehicle accidents in Ontario: a repugnant solution? Wildlife Society Bulletin. 10: 266-270.

This study suggests using a repellant to discourage moose use of salty roadside pools. Results of field testing are presented.

Fraser, D.; Thomas, E. R. 1982. Moose-vehicle accidents in Ontario: relation to highway salt. Wildlife Society Bulletin. 10(3): 261-265.
This article documents moose attraction to roadside salt concentrations and its correlation with vehicle moose collisions. Roadside pools with high salt concentrations were mapped, level of moose use documented, and collisions were evaluated for their distance to salty pools. Moose vehicle collisions appeared to be correlated with salty pools.

Freddy, David J.; Whitcomb, M. B.; Martin, C. F. 1986. Responses of mule deer to disturbance by persons afoot and snowmobiles. Wildlife Society Bulletin. 14(1): 63-68.

Frederick, G. P. 1991. Effects of forest roads on grizzly bears, elk and gray wolves: a literature review. Libby, Montana: U.S. Department of Agriculture, Forest Service, Kootenai National Forest. 54 p.

Free, J. B.; Gennard, D.; Stevenson, J. H.; Williams, I. H. 1975. Beneficial insects present on a motorway verge. Biological Conservation. 8: 61-72.

Fuller, T. K. 1989. Populations dynamics of wolves in north-central Minnesota. Wildlife Monographs. 105: 1-41.
Summarized in Foster & Humphrey 1992; wolf distribution is affected by road density.

Fusari, M. 1982. Feasibility of a highway crossing system for desert tortoises. Washington, DC: U.S. Department of Transportation, Federal Highway Administration; FHWA/CA/TP-81/1. 41 p.

Fusari, M. 1985. A study of the reactions of desert tortoises to different types of fencing. Desert Tortoise Council Proceedings of a Symposium. 1985: 125-132.

Galan, Ortegon F. 1992. Provisional report of the mortality of vertebrates on the roads of Cadiz, September 1991. In: Lopez, Redondo, ed. I jornadas para el estudio y prevencion de la mortalidad de vertebrados en carreteras, Madrid, 5 y 6 de Octubre de 1991. Tomo 2. [Sessions in the study of prevention of road mortalities of vertebrates, Madrid, 5 and 6 October, 1991. Volume 2.]. Ambiental, Madrid: Coordinadora de Organizacciones de Defensa: 66-71.

Garland, T.; Bradley, V. G. 1984. Effects of a highway on Mojave Desert rodent populations. American Midland Naturalist. 111(1): 47-56.
They found that a highway provided a significant barrier to movement (only one individual crossed the road out of 387 recaptured individuals), but mortality rates were not influenced by proximity to the road. They suggest that wide roads inhibit crossings to the extent that kills by automobiles become an unimportant source of mortality for roadside rodent populations.

Gates, J. E. 1990. Highways: the search for solutions. In: Lieberman, S. S., ed. Deer management in an urbanizing region: problems and alternatives to traditional management. Washington, DC: U.S. Humane Society. [Pages unknown].:
Summarized in Foster & Humphrey 1992; roadkill estimates and mitigation suggestions.

Gelegin, V. I.; Ivleva, N. G. 1992. Birds on highways. Sibirskii Biologicheskii Zhurnal. 1992(1): 53-55.
The materials of the present report are the observations and the registrations made in driving journeys on the roads of this country. There were roads with concrete-, asphalt- and metal-covering. Registration was made not only on the roads themselves but also on the both sides of them (within 25 meters). The total length of the routes was 21 695 kilometers and 68,201 individuals belonging to 63 species were counted. These birds are divided into four groups. A decrease of the number of birds on the constant

routes Novosibirsk-Academtown should be noted. Some aspects of bird deaths on the roads are discussed.

George, J. L.; Wingard, R. G.; Palmer, W. L. 1983. Penn State's five-alive deer fence. American Forests.

Germano, David J.; Morafka, David J. 1996. Diurnal aboveground activity by the fossorial silvery legless lizard, *Anniella pulchra*. Great Basin Naturalist. 56(4): 379-380.
The authors report their sighting of a silvery legless lizard aboveground during the middle of the day. The lizard was observed and struck while crossing the road in San Luis Obispo County. This is the first reported observation of this lizard aboveground during the middle of the day.

Getz, L. L.; Best, L. B.; Prather, M. 1977. Lead in urban and rural song birds. Environmental Pollution. 12: 384-388.
Cited in Forman 1995 as an example of roads as a source of toxins.

Getz, L. L.; Verner, L.; Prather, M. 1977. Lead concentrations in small mammals living near highways. Environmental Pollution. 13: 151-157.
Cited in Forman 1995 as an example of roads as source of toxins.

Getz, L. L. 1978. Influence of interstate highways on small mammals. In: Kirkpatrick, C. M., ed. Wildlife and people. The 1978 John S. Wright forestry conference. West Lafayette, IN: Purdue Research Foundation: 81-91.

Getz, L. L.; Cole, F. R.; Gates, D. L. 1978. Interstate roadsides as dispersal routes for *Microtus pennsylvanicus*. Journal of Mammalogy. 59(1): 208-212.
Microtus pennsylvanicus was not found in the Champaign-Urbana area of Illinois prior to 1970. By 1976 it had become abundant in the unmowed grassy vegetation along interstate highways throughout the areas, but was still only associated with interstates or areas connected to interstates by unmowed grassy strips. This is a good example of roadside vegetation as dispersal corridors.

Gibeau, M.; Heuer, K. 1996. Effects of transportation corridors on large carnivores in the Bow River Valley, Alberta. In: Evink, G.; Ziegler, D.; Garrett, P.; Berry, J., eds. Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors: Proceedings of the Florida Department of Transportation/Federal Highway Administration transportation-related wildlife mortality seminar; 1996 April 30-May 2; Orlando, FL. FHWA-PD-96-041. Washington, DC: U.S. Department of Transportation, Federal Highway Administration: 67-79.
They found a 35% highway mortality rate for coyotes in the vicinity of Banff. Over 20 months 21 out of 24 deaths were roadkill. Mouse densities were higher in fenced grassy areas adjacent to the highway, this may be attracting coyotes. Found coyotes were running bighorn sheep into barrier fences and killing them. Also found high mortality rates for black bears (probably because of limited early successional habitats). Underpasses appear to be functioning for resident cougar, but like wolves, it took time to get used to the underpasses (this may have implications for dispersal, i.e., new individuals may not use the underpasses). Highway is a substantial movement barrier to female grizzly, male grizzly do use underpasses, but not often. No successful crossings by wolverine are known, but there have been wolverine road kill. Lynx have been tracked going around fenced portions of the highway rather than going through culverts.

Gibeau, M.; Herrero, S. 1998. Roads, rails and grizzly bears in the Bow River Valley, Alberta. In: Evink, G. L.; Garrett, P.; Zeigler, D.; Berry, J., eds. Proceedings of the international conference on wildlife ecology and transportation; 1998 February 10-12; Ft. Myers, FL. Tallahassee, FL: Florida Department of Transportation: 104-108.
The Bow River Valley is one of the most developed landscapes in the world where grizzly bears persist. Since 1994, we have recorded over 5,000 radio locations for 51 radio-marked grizzly bears in the central Canadian Rocky Mountains. We present preliminary findings on some aspects of how roads and a

railway influenced these bears' movements and behavior. Our results suggest that the Trans-Canada Highway in Alberta, with its high traffic volume, both inside and outside of Banff National Park, is a barrier to female grizzly bear movement, and a significant filter to male movement. This has occurred despite the construction of 12 underpasses in previously fenced sections and another 10 underpasses and two overpasses along the recently fenced section of the highway in the Park. In contrast, eight females have crossed two-lane, secondary highways in other portions of our study area. Three of these females regularly crossed secondary roads. These secondary highways, in contrast with the Trans-Canada Highway, have low traffic volumes during evenings, night, and mornings. All three females that crossed the secondary roads were habituated. This raises another problem. Over 80% of 118 recorded grizzly bear mortalities in Banff National Park between 1971 and 1995 were within 500 meters of a road. We show why certain grizzlies are attracted to near road environments. Most grizzlies, especially long-term survivors, avoid them. We conclude there is a dynamic tension between road avoidance and attraction.

Gibeau, M. L.; Herrero, S.; Kansas, J.; Benn, B. 1996. Grizzly bear population and habitat status in Banff National Park. In: Green, J.; Pacas, L.; Cornwall, L.; Bayley, S., eds. Ecological outlooks project. A cumulative effects assessment and futures outlook of the Banff Bow Valley. Prepared for the Banff Bow Valley Study. Ottawa, Ontario: Department of Canadian Heritage: 6-1. Chapter 6.
The grizzly bear population and habitat in Banff Bow Valley, Banff National Park, and the Central Rockies ecosystem have been seriously stressed by the combined effects of human development and activities. The current status of the Central Rockies grizzly bear population is evaluated using Banff Park mortality and translocation data bases as well as modeling grizzly bear habitat effectiveness, core areas, and linkage zones. Mortality of grizzly bears was 2.92 per year (4.87 - 3.65% of the population), very high for a species with low reproductive rates. Low habitat effectiveness and increasing fragmentation of core security areas were identified as substantial concerns. The Trans-Canada Highway was identified as a significant barrier to grizzly bear movement. Crossing structure and fencing configuration recommendations are included.

Gilbert, M. 1998. The Australian partnership approach to protecting roadside habitats. In: Evink, G. L.; Garrett, P.; Zeigler, D.; Berry, J., eds. Proceedings of the international conference on wildlife ecology and transportation; 1998 February 10-12; Ft. Myers, FL. Tallahassee, FL: Florida Department of Transportation: 189-194.
This paper discusses the importance of roadside habitats for conserving biodiversity and for providing corridors that link larger isolated areas of natural habitat. They have used a partnership approach to develop roadside management plans that conserve the roadside habitat resource.

Gilbert, P. F.; Reed, D. F.; Pojar, T. M. 1971. Migratory deer and Interstate 70 in western Colorado. In: Proceedings of the 51st annual conference of the western association of state game and fish commission. Denver, CO: State of Colorado, Game, Fish, and Parks Department: 436-446.

Gilbert, T. 1982. Evaluation of deer mirrors for reducing deer/vehicle collisions. Washington, DC: U.S. Department of Transportation, Federal Highway Administration; FHWA/RD-82/061. 14 p.

Gilbert, T.; Wooding, J. 1994. Chronic roadkill problem areas for black bear in Florida. Orlando, FL: Florida Game and Fresh Water Fish Commission. [Pages unknown].

Gilbert, T.; Wooding, J. 1996. An overview of black bear roadkills in Florida, 1976-1995. In: Evink, G.; Ziegler, D.; Garrett, P.; Berry, J., eds. Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors: Proceedings of the Florida Department of Transportation/Federal Highway Administration transportation-related wildlife mortality seminar; 1996 April 30-May 2; Orlando, FL. FHWA-PD-96-041. Washington, DC: U.S. Department of Transportation, Federal Highway Administration: 308-322.
Roadkills occurred most often during the fall. They conducted GIS analysis of roadkill locations. Twelve problem areas accounted for 30% of roadkills. Eleven of the 12 areas were on two-lane roads

and one was on a four-lane. Ten of the 12 areas were totally or partially bounded by public land ownerships. Black bear roadkills have increased over time. Landscape characteristics associated with problem areas include large forested areas (wooded wetlands, basin swamps, intermittent drainages or defined streams and their floodplains). Highway underpasses have been generally successful in reducing roadway mortality of bears and panthers.

Gilbert, T. 1998. Technical assistance and agency coordination on wildlife and habitat conservation issues associated with highway projects in Florida. In: Evink, G. L.; Garrett, P.; Zeigler, D.; Berry, J., eds. Proceedings of the international conference on wildlife ecology and transportation; 1998 February 10-12; Ft. Myers, FL. Tallahassee, FL: Florida Department of Transportation: 209-213.
Biologists with the Florida Game and Fresh Water Fish Commission coordinate with the Florida Department of Transportation on a statewide basis by providing technical assistance to identify and resolve wildlife issues during the highway project development and design phase. Major issues addressed on new highways or improvement projects include the loss of habitat, fragmentation and isolation of habitat systems, management and protection of public lands, highway mortality of listed species, wildlife taking issues involving listed species or their nests, and appropriate mitigation strategies. On major projects, our biologists work as a team member with FDOT highway design and environmental personnel in a formal partnering effort over several years to identify the scope of the problem, and determine solutions which will avoid, minimize, or mitigate impacts to fish and wildlife resources. Information from our agency's wildlife and habitat geographic information system data base is provided to FDOT for use in alignment analysis and impact assessment. Our biologists also provide input to FDOT on the justification, design, and siting of wildlife underpasses, and bridge extensions over river floodplains to maintain habitat connectivity. We annually assist in training FDT environmental personnel in wildlife and habitat identification, impact assessment, and survey techniques. Our agency has developed and manages a statewide system of regional mitigation banks, including the 1,770-acre Platt Branch Mitigation Park in Highlands County which is used exclusively by FDOT to mitigate highway projects. Examples of the resolution of wildlife issues through mediation and partnering are the northern extension of Florida’s Turnpike, and the Suncoast Expressway Project 1.

Gill, J. A.; Sutherland, W. J.; Watkinson, A. R. 1996. A method to quantify the effects of human disturbance on animal populations. Journal of Applied Ecology. 33(4): 786-792.
The extent and consequences of human disturbance on populations of vertebrates are contentious issues in conservation. As recreational and industrial uses of the countryside continue to expand, it is becoming increasingly important that the effects of such disturbance on wildlife are quantified. This study describes a method of quantifying the effect of disturbance, based on measuring the trade-off between resource use and risk of disturbance. This approach is based on one used by ethologists to study the effects of predation risk on patch use. Pink-footed geese, *Anser brachyrhynchus*, feeding on arable fields, are highly responsive to disturbance from surrounding roads. The extent to which these fields are exploited declines linearly with increasing risk of disturbance. The reduction in use of these feeding grounds caused by disturbance can be quantified by translating the biomass of food not exploited into the number of birds that this food could have supported. This approach allows both quantification of the impact of disturbance on a population, and exploration of the potential consequences of changes in disturbance on the size of populations.

Gittins, P. 1983. Road casualties solve toad mysteries. New Scientist. 97: 158-162.

Gleason, J. S.; Jenks, J. A. 1993. Factors influencing deer/vehicle mortality in east-central South Dakota. Prairie Naturalist. 25: 281-287.

Gleim, James A.; Case, Ronald M. 1976. Effect of vegetation on road-killed wildlife on Interstate 80. Proceedings Nebraska Academy of Science. 86: 16-17.

Godfrey, Paul J. 1979. Response of coastal ecosystems to the mechanical stress of off-road vehicles. British Ecological Society Symposium. 19: 641-642.

Goodman, S. M.; Pigeon, M.; O'Connor, S. 1994. Mass mortality of Madagascar radiated tortoise caused by road construction. Oryx. 28(2): 115-118.

Goodwin, G. A.; Ward, A. L. 1976. Mule deer mortality on Interstate 80 in Wyoming: causes, patterns and recommendations. Res. Note RM-332. Ft. Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. [Pages unknown].

Goosem, M. 1993. Critters, cars, carnage, connectivity and culverts. Repercussions of rainforest roads. North Queensland Naturalist. 95: 24-28.

Goransson, G.; Karlsson, J.; Lindgren, A. 1978. Influence of roads on the surrounding nature. 2. Fauna. [Location of publisher unknown]: National Swedish Environmental Protection Board; No. SNV PM069. 124 p.

Goransson, G.; Karlsson, J. 1979. Changes in population densities as monitored by animals killed on roads. Naturvardsverket Rapport. 151: 120-125.

Gordon, D. F. 1969. Deer mirrors: a clearer picture. Denver, CO: Colorado Department of Natural Resources, Division of Game, Fish and Parks. [Pages unknown].; Game Information Leaflet No.77.

Gordon, K. 1932. Rabbits killed on an Idaho highway. Journal of Mammalogy. 13: 169-173.

Gossmann, Koellner S.; Eisfeld, D. 1990. The suitability of the Black Forest as habitat for the lynx (*Lynx lynx* L.). Mitteilungen Des Badischen Landesvereins Fuer Naturkunde Und Naturschutz E V Freiburg Im Breisgau. 15(1): 177-246.
The lynx (*Lynx lynx* L.1758) was indigenous to the Black Forest until the 17th century. At the end of the 30-Year War, an increased persecution of the lynx by means of hunting began. This subsequently caused an almost complete disappearance by the end of that century and finally lead to a total extinction during the 18th century. Derived from Wuerttemberg hunting records from the beginning of the reduction period, the former lynx density was 1.5 lynx/100 km^2. The present day suitability of the Black Forest as an appropriate habitat for the lynx has been concluded based on experiences made in neighboring countries with lynx populations. Accordingly, the Black Forest with its expansive forests (percentage of entire forest area is 66%) offers sufficient shelter and retreat space. Since wild lynx are absolutely harmless towards people, their presence even might become a tourist attraction. The Black Forest offers favorable habitat conditions to lynx. Damage caused by these animals will be small. Therefore their reintroduction to the Black Forest is recommended. For release, a site in the northern part of the area should be considered.

Gragera, Diaz F.; Corbacho, M. A.; de-Avalos, Schlegel J. 1992. Provisional report of the mortality of vertebrates on the roads of Badajoz Province, September 1991. In: Lopez, Redondo, ed. I jornadas para el estudio y prevencion de la mortalidad de vertebrados en carreteras, Madrid, 5 y 6 de Octubre de 1991. Tomo 2. [Sessions in the study of prevention of road mortalities of vertebrates, Madrid, 5 and 6 October, 1991. Volume 2.]. Ambiental, Madrid: Coordinadora de Organizacciones de Defensa: 136-144.

Graves, H. B.; Bellis, E. D. 1971. Deer and motorists--can they coexist? Pennsylvania Game News. 42(12): 40-42.

Green, J. E.; Raine, M.; Jorgenson, J. and others. 1997. The mid-point interchange project: assessment of the proposed modifications to the Stewart Creek primary wildlife movement corridor and recommendations for mitigation. Canmore, Alberta: Mid-Point Interchange Committee; Unpublished report. 28 p.
This document evaluates the effects of a proposed highway interchange on a regionally significant

wildlife movement corridor. A mitigation strategy including highway fencing and wildlife crossing structures is proposed.

Greenwood, J. G. 1989. Sandwich terns apparently using roads as navigational cues. British Birds. 2(3):117.

Gregori, J. 1987. Birds dying also on roads. Acrocephalus (Ljubljana). 31-32: 19-22.

Groebner, Daniel J.; William, L. R. 1988. Use of roads and circadian movement rates of a pair of wolves. Journal of the Minnesota Academy of Science. 53(3): 18-19.

Groot Bruinderink, G. W. T. A.; Hazebroek, E. 1996. Ungulate traffic collisions in Europe. Conservation Biology. 10(4): 1059-1067.
The expansion of highways and roads can fragment natural habitats and thus decrease the viability of ungulate subpopulations. It can also increase the number of vehicle collisions with wildlife. Although collisions apparently contribute to only a minor part of the annual mortality for most ungulate populations, they have become a serious road-safety problem in Europe, the United States, and Japan. To better understand this threat to biodiversity and road safety, we reviewed European and, secondarily, North-American and Japanese literature on ungulate traffic collisions. In contrast to the results of some long-term studies, we argue that the relationship suggested between the number of road kills and traffic volume is confounded by population dynamics, changes in traffic volume, and sampling intensity. Although sexes may run distinct seasonal risks of collision, the age and sex composition of road kills reflect population structure in the field. We also argue that observed seasonal and daily patterns in the number of road kills, related to life-history features of the species involved, should form the template for solutions to the problem. We found no strong evidence of the effects of permanent warning signs, 90 degrees light mirrors, scent, or acoustic fencing on the number of kills per crossing. To reduce the risk of ungulate traffic collisions, we recommend a combination of fencing and wildlife passages for roads and railroads that combine high traffic volume with high speed. For secondary roads we recommend seasonal application of intermittently lighted warning signs, triggered if possible by the ungulates. We emphasize the need for educational programs.

Grover, Mark C.; DeFalco, Lesley A. 1995. Desert tortoise (*Gopherus agassizii*): status-of-knowledge outline with references. Gen. Tech. Rep. INT-316. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station 134 p.

Grue, C. E.; Hoffman, D. J.; Beyer, W. N.; Franson, L. P. 1986. Lead concentrations and reproductive success in European starlings (*Sturnus vulgaris*) nesting within highway roadside verges. Environmental Pollution (Series A). 42: 157-182.

Gunther, K. A.; Biel, M. J.; Robison, H. L. 1998. Factors influencing the frequency of road-killed wildlife in Yellowstone National Park. In: Evink, G. L.; Garrett, P.; Zeigler, D.; Berry, J., eds. Proceedings of the international conference on wildlife ecology and transportation; 1998 February 10-12; Ft. Myers, FL. Tallahassee, FL: Florida Department of Transportation: 32-42.
During the 8 year (1989 to 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 vehicles 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, vehicles caused wildlife mortality does not appear to have a significant negative impact on large mammal populations in the park. However, road-killed carcasses appear to be a significant source of nutrition for some individual carnivores and scavengers whose home ranges encompass wildlife carcass disposal sites.

Guyot, G.; Clobert, J. 1997. Conservation measures for a population of Hermann's tortoise (*Testudo hermanni*) in southern France bisected by a major highway. Biological Conservation. 79: 251-256.
Between May 1989 and October 1990 a highway was constructed through the core area of one of the largest French populations of *Testudo hermanni*, a species seriously threatened by habitat loss and habitat fragmentation. Two general strategies were used to alleviate negative impacts of the highway on the tortoise population: first, 300 tortoises, that were directly affected by the highway construction, were temporarily maintained in outdoor enclosures and relocated after construction was completed; secondly, attempts were made to reduce traffic impacts on the tortoise population, including the use of fences to keep tortoises off the road and the construction of culverts and a tunnel under the road to provide for movements of animals between the separated habitat areas. The short-term outcome of this conservation exercise was a success: the annual survival rate of 78% observed in reintroduced tortoises was comparable to published results of translocation of other tortoise species into unfamiliar habitat; traffic mortality of tortoises in the 4 years following highway construction was low and mark-recapture results indicate a stable adult population and the use of the culverts and the tunnel by tortoises to cross the road.

Halls, L. K.; Boyd, C. E.; Lay, D. W.; Goodrum, P. D. 1965. Deer fence construction and costs. Journal of Wildlife Management. 29: 885-888.

Hamann, H. J.; Schmidt, K. H.; Wiltschko, W. 1995. Barrier effect of a superhighway on hole-nesting passerines. Verha. Dtsch. Zool. Ges. 88(1): 32-35.

Hamel, Paul B. 1996. *Agkistrodon piscivorus leucostoma* (western cottonmouth). Carrion feeding. Herpetological Review. 27(3): 143-145.
The author describes his observations of a western cottonmouth feeding on the body of a road-killed snake in Tennessee.

Hamer, M. 1994. Carcass count reveals rising death toll on the roads. New Scientist. 141(19): 8-13.

Hamer, M. 1994. Cameras keep death off the roads. New Scientist. 142(1920): 9-14.

Haner, Thomas W.; Moulton, Michael P.; Choate, Jerry R.; Redfearn, Todd P. 1996. Species composition of small mammals at an interstate highway interchange. Southwestern Naturalist. 41(2): 192-194.
Researchers conducted a small mammal trapping survey at an interstate highway interchange in Ellis County, Kansas in the summer of 1991. Species composition and number of individuals from each species is reported.

Hanna, P. 1982. The impact of Interstate Highway 84 on the Sublette-Black Pine migratory deer population. A 12-year summary, with recommendations for mitigation of identifiable adverse impacts. Boise, ID: Idaho Department of Fish and Game; Project W-160. 97 p.
Describes I-84 as a barrier to migration, resulting in expensive winter feeding and increased collision rates. Deer do not use existing underpasses (not designed for deer passage).

Hanowski, J. A. M.; Niemi, G. J. 1995. A comparison of on- and off-road bird counts - do you need to go off road to count birds accurately. Journal of Field Ornithology. 66(4): 469-483.
On- and off-road point counts were established in two national forests in northern Minnesota to determine whether breeding bird parameters derived from two different types of counts conducted on- or off-road were comparable. The first design compared single-year counts randomly placed along a

road (like the U.S. Fish and Wildlife Service breeding bird survey) and counts conducted at least 200 meters from the road that were placed in a specific habitat. In the second approach, differences and similarities were examined in data gathered over 3 years from points placed near roads to points in the same habitat (stand) >200 meters from the road. Data from the first approach indicated that on average, two more species and four more individuals were observed on roadside counts than on off-road counts. Twenty-four individual species were more abundant on road than off road. Many of these species were ones associated with openings or shrubs that develop along roads. Of the five species that were more abundant on the off-road counts, three had specific associations with lowland conifer habitat, which was not as commonly sampled with the on-road counts. Data from the second approach indicated that number of species, individuals, and individual species-abundance patterns were similar between the paired within-stand points. Greater statistical power was achieved for data gathered with habitat specific counts off-road primarily because standard errors were lower for bird parameters in this data set than in the data collected on road. It is suggested that points can be placed on roads with the restriction that points be selected randomly and placed within distinct habitat types, and that roads selected for sampling have a closed canopy. Evidence provided here also suggest that some points be placed off road in habitats not sampled with on-road counts.

Hansen, C. S. 1983. Costs of deer-vehicle accidents in Michigan. Wildlife Society Bulletin. 11: 161-164.
The average cost of a deer-vehicle accident in Michigan in 1978 was approximately $648 for property damage, injury, and loss of life. Costs of deer vehicle accidents are lower than the average for all types of accidents. Total social costs of deer vehicle collisions were >$10,000,000 in Michigan in 1978.

Hansen, C. S. 1983. Costs of deer related automotive accidents. University of Michigan Transportation Research Review. 14: 9-12.

Hansen, Lindhard. 1982. Road kills in Denmark. Dan. Ornithol. Foren. Tidsskr. 76(3-4): 97-110.

Hanski, I. L.; Gilpin, M. E. 1997. Metapopulation biology: ecology, genetics, and evolution. Orlando, FL: Academic Press. 512 p.

Hansson, L. 1991. Dispersal and connectivity in metapopulations. Biological Journal of the Linnean Society. 42: 89-103.
This paper reviews characteristics of dispersal that influence metapopulation functioning, such as releasing factors, density dependence, timing and types and health of dispersers. Economic thresholds, intraspecific conflicts and avoidance of inbreeding are often regarded as the key ultimate or proximate (or both) causes of dispersal, but there is no consensus about the most important mechanisms. Dispersing individuals are often considered to differ genetically from the residents but good supporting evidence has only been presented for some insect species. Sex and age differences in dispersal rates are most common in polygamous species and in long-lived species with many litters per female. A bimodal distribution of dispersal distances, earlier thought to be a common pattern, is probably an artifact caused by habitat heterogeneity and varying survival of settled individuals. Dispersal distances are longer in poor environments. Habitat specialists are more affected by boundaries during dispersal than generalists. Dispersal just before or during the early reproductive season is common in certain species occupying early successional habitats. Dispersal increased both population and metapopulation size and persistence in plants, insects and small mammals.

Harding, B. D. 1986. Short-eared owl mortality on roads. British Birds. 9(8): 403-404.
Twelve short-eared owl carcasses were found on 8 kilometers of English road from 11/82 to 2/83.

Harper, W. L.; Lougheed, D. N. 1988. A guide for the installation of 2.5 meter ungulate exclusions fencing on highway right-of-ways. Vancouver, BC: British Columbia, Ministry of Transportation; Unpublished report. [Pages unknown].

Harris, L. D.; Scheck, J. 1991. From implications to applications: the dispersal corridor principle applied to the conservation of biological diversity. In: Saunders, D. A.; Hobbs, R. J., eds. Nature conservation 2: the role of corridors. Chipping Norton, Australia: Surrey Beatty and Sons: 189-220.

Harris, L. D.; Scheck, J. 1991. New initiatives for wildlife conservation: the need for movement corridors. In: Mackintosh, G., ed. Preserving communities and corridors. Washington, DC: Defenders of Wildlife: 11-34.

Harris, L. D.; Silva-Lopez, G. 1992. Forest fragmentation and the conservation of biological diversity. In: Fiedler, PL; Jain, SK, eds. Conservation biology: the theory and practice of nature conservation, preservation and management. New York: Chapman and Hall: 197-237.

Harrison, G.; Hooper, R.; Jacobsen, P. 1980. Trans-Canada Highway wildlife mitigation measures, Banff National Park (east gate to Banff traffic circle). Banff, Alberta: Parks Canada, Western Region. [Pages unknown].

Hartnigk, Kummel C. 1984. The moss mites (Acari: Oribatei) of an oak-pine forest soil in Berlin (West): comparison of 3 sampling plots differently influenced by road construction and traffic. Zoologische Beitraege. 8(2): 207-230.

Haslinger, H. 1989. Migration of toads during the spawning season at Stallauer Weiher Lake, Bad Tolz, Bavaria. In: Langton, T. E. S., ed. Amphibians and roads. Proceedings of the Toad Tunnel Conference; 1989 January 7-8; Rendsburg, Federal Republic of Germany. Shefford, England: ACO Polymer Products Ltd.: 181-182.

Haug, Elizabeth. 1985. Merlin deeding on road-kills. Raptor Research. 19(2/3): 103-105.

Havlin, Jiri. 1987. Motorways and birds. Folia Zoology. 36(2): 137-153.

Hawkins, R. E.; Ooag, W. D.; Klimstra, O. U. and others. 1970. Significant mortality factors of deer on Crab Orchard National Wildlife Refuge. Transactions of the Illinois State Academy of Science. 63: 202-206.

Hellgren, E. C.; Vaughan, M. R.; Stauffer, D. F. 1991. Macrohabitat use by black bears in a southeastern USA wetland. Journal of Wildlife Management. 55(3): 442-448.

We determined habitat use by black bears (*Ursus americanus*) in the Great Dismal Swamp of Virginia and North Carolina by radiotracking 24 female and 16 male bears. On a year-round basis, females preferred ($P < 0.05$) pocosins and mesic areas and males preferred gum-cypress (*Nyssa* spp.-*Taxodium distichum*) and maple-coniferous (*Acer* spp.-*Pinus* spp.) stands. Females preferred ($P < 0.05$) pocosins and disturbed areas during summer months, mesic and gum-cypress habitats in early fall, and pocosins in late fall. Females used maple-dominated habitats less ($P < 0.05$) than their availability throughout the year. Roads were preferred ($P < 0.05$) by females during all seasons except early fall, when females made excursions to feeding areas far from roads. Maintenance and enhancement of pocosins, mature gum, oak (*Quercus* spp.), and disturbed habitats would benefit black bears in southeastern wetlands by providing a wide variety of natural foods throughout the year.

Henein, K.; Merriam, G. 1990. The elements of connectivity where corridor quality is variable. Landscape Ecology. 4: 155-170.

Small mammals in heterogeneous environments have been found to disperse along corridors connecting habitat patches. Corridors may have different survivability values depending on their size and the degree of cover they provide. This deterministic model tests the effects of varying corridor quality on the demographics of a metapopulation of *Peromyscus leucopus*. Two types of corridors are defined based on the probability of survival during a dispersal event. Results indicate that mortality during movement through corridors influences metapopulation demographics. We found that: 1) Any connection between two isolated patches is better than no connection at all in terms of persistence and

population size at equilibrium. 2) Metapopulations with exclusively high quality corridors between patches have a larger population size at equilibrium than do those with one or more low quality corridors. 3) Increasing the number of high quality corridors between patches has a positive effect on the size of the metapopulation while increasing the number of low quality corridors has a negative effect. 4) The addition to a metapopulation of a patch connected by low quality corridors has a negative effect on the metapopulation size. This suggests the need for caution in planning corridors in a managed landscape. 5) There is no relationship between the number of corridors and the metapopulation size at equilibrium when the number of connected patches is held constant. 6) Geometrically isolated patches connected by low quality corridors are most vulnerable to local extinctions. We conclude that corridor quality is an important element of connectivity. It contributes substantially to the effects of fragmentation and should be carefully considered by landscape planners.

Henry, P.; Epain, Henry C. 1989. Amphibian protection on Highway A71 in Sologne, France. In: Langton, T. E. S., ed. Amphibians and roads. Proceedings of the Toad Tunnel Conference; 1989 January 7-8; Rendsburg, Federal Republic of Germany. Shefford, England: ACO Polymer Products Ltd: 191-192.

Herbstritt, R. L.; Marble, A. D. 1996. Current state of biodiversity impact analysis in state transportation agencies. Transportation Research Record. 1559: 51-63.
The Transportation Research Board's Task Force on Natural Resources conducted a survey of state transportation agencies in early 1995 to determine the current state of biodiversity analysis in the transportation community, the extent to which biodiversity is becoming an emerging issue for state departments of transportation, and how the issue is being managed. Sixty-six percent of the 32 responding DOTs indicated that biodiversity was an issue in transportation planning.

Hern. 1988. Road mortality of the little owl (*Athene noctua*) in Spain. Journal of Raptor Research. 22(3): 81-84.

Heuer, K. 1995. Wildlife corridors around developed areas of Banff National Park (1995 progress report). Banff, Alberta: Parks Canada, Banff Warden Service 78 p.
This survey considered wildlife movement through corridors of natural land near human developments in Banff National Park. Corridors are evaluated in four study areas. Snow tracking transects were used to identify wildlife movement corridors. Factors that influenced wildlife movement included urban development, highway fencing, water barriers, cliffs, and highway underpass locations.

Heuer, K.; Owchar, R.; Duke, D.; Antonation, S. 1998. Wildlife corridors around developed areas of Banff National Park. Progress report, winter 1996/1997. Banff, Alberta: Parks Canada, Banff National Park Warden Service 46 p.
This is the fourth progress report for wildlife corridor surveys around six study areas in Banff National Park. Snow tracking transects were used to monitor wildlife use of previously identified movement corridors. Focal species included carnivores and ungulates. Location and level of use are described for each corridor.

Heusmann, H. W. 1973. How to create wildlife habitat from highway construction. Catalyst. 3(4): 17-19.

Heusmann, Harry W. 1969. An analysis of the potential creation of productive wetlands by interstate highway construction with emphasis on waterfowl management. Boston: University of Massachusetts. 97 p. M.S. thesis.

Hewitt, D. G.; Cain, A.; Tuovila, V.; Shindle, D. B.; Tewes, M. E. 1998. Impacts of an expanded highway on ocelots and bobcats in southern Texas and their preferences for highway crossings. In: Evink, G. L.; Garrett, P.; Zeigler, D.; Berry, J., eds. Proceedings of the international conference on wildlife ecology and transportation; 1998 February 10-12; Ft. Myers, FL. Tallahassee, FL: Florida Department of Transportation: 126-134.
Vehicle collisions are a significant cause of mortality for the endangered ocelot (*Leopardus pardalis*) in southern Texas. To minimize such impacts, the Texas Department of Transportation (TxDOT) has

designated and modified culverts to facilitate ocelot road crossings near occupied or potentially occupied ocelot habitat. Culverts were recently modified in connection with a project expanding a section of U.S. Highway 281 in Live Oak County, Texas where potential ocelot habitat occurs. Our objectives were to assess the likelihood that an ocelot population exists in the area, determine the effects of the highway expansion on resident ocelots, and to assess the effectiveness of the highway crossing structures for free-ranging cats. To date, we have not documented ocelots in the study area; however, our trapping effort will continue for another 6 months. We have captured and radio-collared seven bobcats (*Lynx rufus*) that will be used as surrogates for the similarly-sized ocelot. We have documented radio-collared bobcats crossing the expanded section of the highway and that used the highway culverts for both daybeds and crossing structures. A roadkill survey has shown a large number of vehicle-related mortalities along the expanded section of highway, including one radio-collared bobcat. This project, which will be completed in 1999, will provide information necessary for TxDOT to evaluate the effects of roads on ocelots and bobcats and to determine if crossing structures are effective and which structural design is used most readily by a variety of wildlife species.

Hicks, A. C. 1993. Using road-kills as an index to moose population change. Alces. 29: 243-247.
They conducted a literature review of road kill rates as population indices. They propose that existing studies suggest that moose vehicle collision rates could indicate population trends or support the findings of other indices.

Hines, Jim. 1977. Environmentally disruptive road construction in the Qu'appelle Valley. Blue Jay. 35(4): 200-204.

Hines, T. D.; Case, R. M. 1991. Diet home range movements and activity periods of swift fox in Nebraska, USA. Prairie Naturalist. 23(3): 131-138.
Information was obtained from 23 live-trapped swift fox (*Vulpes velox*). Eight foxes were aged using the cementum annulus method; they averaged 1.25 years old. Mammals and insects were the most frequently (100% and 56%, respectively) occurring items found in 52 scats. However, 54% of the scats contained plants material and 40% birds. Dens were located near roads. Home ranges of seven adults averaged 32.3 kilometer squared. These home ranges are larger than those for any other fox (*Vulpes* spp.) that we could find in the literature. Swift foxes were radio-located within 1 kilometer of roads 66% of the time. Swift fox traveled an average 13.1 kilometers for each of 47 nights that they were radio-tracked. Activity period commenced between 1800 and 2000 hr and ceased between 0300 and 0600 hr mountain standard time. Only females with pups moved diurnally. Hourly distance traveled averaged 1.2 kilometers during the activity periods.

Ho, Y. B.; Tai, K. M. 1988. Elevated levels of lead and other metals in roadside soil and grass and their use to monitor aerial metal depositions in Hong Kong. Environmental Pollution (Series A). 49: 37-51.

Hobbs, R. J.; Hussey, B. M. J.; Saunders, D. A. 1990. Nature conservation: the role of corridors. Bulletin of the Ecological Society of America. 1(1): 48-49.

Hodgman, T. P.; Harrison, D. J.; Katnik, D. D.; Elowe, K. D. 1994. Survival in an intensively trapped marten population in Maine. Journal of Wildlife Management. 58(4): 593-600.
Marten (*Martes americana*) are susceptible to overharvesting, and forestry practices may compound this problem by reducing habitat quality and increasing accessibility of trappers via forest roads. From May 1989 through December 1991, we estimated age- and sex-specific survival of marten in a logged area with road access. We tested for age- and sex-specific differences in survival, combined estimates of survival with published natality rates to evaluate whether harvests were sustainable, and simulated population response to management options. Trapping accounted for 90% of all documented mortalities (n = 49) among 38 radio-collared female (26 ad, 12 juv) and 36 radio-collared male (24 ad, 12 juv) marten. Most (93%) trapping-caused mortality occurred during the first 14 days of the season, during which vulnerability of adult females to trapping was 1.45-1.75 times less ($P < 0.01$) than for other age-sex classes. Survival from 1 May to 15 December was higher ($P = 0.03$) for adult females (0.39) than

adult males (0.12). Harvests of female marten were not sustainable, and shortening the trapping season from 6 to 2 weeks would be ineffective at achieving a finite rate of population change (lambda) greater-than-or-equal-to 1.0. Unless immigration compensated for emigration and trapper-caused mortality, we estimated that survival of females would need to nearly double to sustain the population. Access by trappers via logging roads increases the potential for declines in marten populations. Regulations to reduce trapping-caused mortality may be needed to maintain viable marten populations in landscapes with extensive forest harvesting and intensive trapping.

Hodson, N. L. 1962. Some notes on the causes of bird road causalities. Bird Study. 9: 168-173.

Hodson, N. L.; Snow, D. W. 1965. The road deaths enquiry, 1960-1961. Bird Study. 12: 168-172.

Hodson, N. L. 1966. A survey of road mortality in mammals (and including data for the grass snake and common frog). London: Journal of Zoology. 148: 576-579.

Hofstra, G.; Hall, R. 1971. Injury on roadside trees: leaf injury on pine and white cedar in relation to foliar levels of sodium and chloride. Canadian Journal of Botany. 49: 613-622.

Hofstra, G.; Smith, D. W. 1984. The effects of road deicing salt on the levels of ions in roadside soils in southern Ontario. Journal of Environmental Management. 19(3): 261-271.

Holbrook, H. T.; Vaughan, M. R. 1985. Influence of roads on turkey mortality. Journal of Wildlife Management. 9(3): 611-614.

Holisova, V.; Obrtel, R. 1986. Vertebrate casualties on a Moravian road. Prirodoved. Pr. Ustavu Cesk. Akad. Ved. Brne. 20(9): 1-43.

Holmes, T. L.; Knight, R. L.; Stegall, L.; Craig, G. R. 1993. Responses of wintering grassland raptors to human disturbance. Wildlife Society Bulletin. 21: 461-468.
We measured the flushing responses and flush distances of six species of diurnal raptors (American kestrels, merlins, prairie falcons, rough-legged hawks, ferruginous hawks, and golden eagles) exposed to walking and vehicle disturbances during winter in northern Colorado. Walking disturbances resulted in more flushes than vehicle disturbances for all species except prairie falcons. Although flush distance did not vary with disturbance type for the 3 falcon species, rough-legged hawks and golden eagles flushed at greater distances for walking disturbances and ferruginous hawks flushed at greater distances for vehicle disturbances. Merlins and prairie falcons perched along paved roads had shorter flush distances to walking disturbances than individuals perched along gravel roads. Rough-legged hawks perched nearer to the road flushed at greater distances than those farther away. American kestrels, prairie falcons, and ferruginous hawks perched closer to the ground had greater flush distances than those perched higher. Dark-morph ferruginous and rough-legged hawks flushed at greater distances than light morphs. For walking disturbances, a linear relationship existed between flight distance and body mass, with lighter species flushing at shorter distances; however, this trend did not hold for vehicle disturbances.

Hop, Kevin D.; Kenneth, F. H.; David, E. N. 1989. Vertebrate wildlife use of highway borrow pit wetlands in South Dakota. Proceedings of the South Dakota Academy of Science. 68: 47-54.

Hope, Jones P. 1987. Bird scavengers on Gwynedd road in 1986. Gwynedd Bird Report. 986: 55-57.

Hoppop, Ommo; Hoppop, Kathrin. 1995. The influence of agriculture and road usage on the distribution of coastal bird nests on saltmarshes in Schleswig-Holstein (Germany). Vogelwarte. 38(2): 76-88.
The authors studied the effect of agriculture and road traffic on populations of oystercatchers, black-headed gulls, arctic terns, herring gulls, common gulls, and common terns on the Saltmarsh Island of

Nordstrandischmoor, Germany. Nest distances from the road and population sizes were influenced by the proximity to pedestrians and to cultivated areas.

Horkel, J. D.; Lutz, R. S.; Silvy, N. J. 1981. Rights-of-way as habitat for the endangered Attwater's prairie chicken. In: Tillman, R. E., ed. Proceedings of second symposium on environmental concerns in rights-of-way management; 1979 October 16-18; Ann Arbor, MI. Ann Arbor: University of Michigan: 65-65.

Hornbeck, G. E. 1990. Wildlife mitigation on Highway 40 for the XV (1988) Olympic winter games. Edmonton, Alberta: Alberta Fish and Wildlife; Unpublished report. [Pages unknown].
Discusses mitigation techniques used (signing, increased law enforcement, supplemental feeding, avoidance of salt) along a road that passes through elk winter range and is normally closed in winter.

Hsu, M.; Peterle, T. J. 1989. Use of artificial nest cavities along Ohio interstate highways by bluebirds (*Sialia sialis*) and mice (*Peromyscus*). Ohio Journal of Science. 89(2): 44-52.

Hsu, Martha T. 1984. Roadside deicing chemical accumulation after 10 years. Transportation Research Record. 969: 36-40.

Hubbs, A. H.; Boonstra, R. 1995. Study design to assess the effects of highway median barriers on wildlife. Downsview, Ontario: Research and Development Branch, Ministry of Transportation; MAT-94-03. 49 p.
This report presents a simple and cost-effective study design to assess the effects of concrete median barriers on wildlife along multiple lane highways in southern Ontario. The effects on mortality of key wildlife species along Highway 401 were to be determined by designing a road-kill study implementable by highway maintenance crews, with the possibility of expanding the study to other highways and/or addressing other possible effects on wildlife. The report discusses the wildlife species, issues, and hypotheses of particular interest, then summarizes current knowledge of roadway barrier effects on wildlife mortality, movements, and species diversity. The proposed study design is based on collection of road-kills for a minimum of five years from selected 2-kilometer stretches of highway with and without concrete barriers, and is focused on 14 species of medium and large sized mammals including valuable game and fur-bearing species.

Hubert, G. F. 1991. Striped skunk investigations: striped skunk road-kill survey. [Location of publisher unknown]: Illinois Department of Conservation; IL W-099-R-3/Job 1/Study XI. 20 p.
Monthly records of striped skunk road-kills were maintained for 492,988 miles driven in 1990 by project personnel in various wildlife- related organizational units. A skunk population index based on the number of road- kills observed per 1,000 miles sampled was calculated on a seasonal and annual basis.

Hubert, G. F. 1991. Cottontail rabbit investigations: cottontail rabbit road-kill survey. [Location of publisher unknown]: Illinois Department of Conservation; IL W-099-R-3/Job 1/Study I. 20 p.
Monthly records of cottontail rabbit road-kills were maintained for 492,988 miles driven in 1990 by project personnel in various wildlife- related organizational units. A cottontail population index based on the number of road-kills observed per 1,000 miles sampled was calculated on a seasonal and annual basis.

Huey, L. M. 1941. Mammalian invasion along the highway. Journal of Mammalogy. 22: 383-385.

Huijser, M. P.; Bergers, P.; de Vries, H. 1998. Hedgehog traffic victims: how to quantify effects on the population level and the prospects for mitigation. In: Evink, G. L.; Garrett, P.; Zeigler, D.; Berry, J. , eds. Proceedings of the international conference on wildlife ecology and transportation; 1998 February 10-12; Ft. Myers, FL. Tallahassee, FL: Florida Department of Transportation: 171-180.
In western Europe hedgehogs are frequently killed by traffic. One of the reasons a reduction of the number of traffic victims is desirable is because of possible negative effects on local populations. We discuss four methods which quantify the effects on populations by using the hedgehog as an example. Two of these methods (i.e., reasoning based on available knowledge and determining the relative

importance of traffic mortality through radio-telemetry or capture-mark-recapture studies) are not recommended because they can be unprecise, subjective, do not address the variables that really matter, have no general validity, or may not allow for statistical tests. The third method estimates the effect on population size by comparing relative animal densities in road and control plots, while the fourth concerns a future model in which the effect of traffic mortality is related to the survival probability of a (local) population. The third and fourth methods do not have severe drawbacks but cannot be conducted without detailed knowledge on the ecology and population dynamics of the species concerned. Furthermore, a model may provide key factors which may prove valuable in the process of mitigation, Finally, a method is presented to investigate the prospects for the reduction of hedgehog traffic victims. The composition of the landscape in a zone adjacent to a road is related to the location of hedgehog traffic victims. If strong relations are found, adaptations of the landscape combined with wildlife passages may follow.

Hull, Christopher N. 1979. A comparative study of bird populations on a wooded expressway median. Jack-Pine Warbler. 57(4): 184-189.

Hunt, A.; Dickens, H. J.; Whelan, R. J. 1987. Movement of mammals through tunnels under railway lines. Australian Zoologist. 24(2): 89-93.

Illner, H. 1992. Effect of roads with heavy traffic on grey partridge (*Perdix perdix*) density. Gibier Faune Sauvage. 9: 467-480.

Ilner, H. 1992. Road deaths of Wesphalian owl; methodological problems, influence of road type and possible effects on population levels. In: Galbraith, C. A.; Taylor, I. R.; Percival, S. M., eds. The ecology and conservation of European owls. Peterborough, UK: Peterborough Joint Nature Conservation Committee: 94-100.

Ingebrigtsen, D. K.; Ludwig, J. R. 1986. Effectiveness of Swareflex wildlife warning reflectors in reducing deer-vehicle collisions in Minnesota. St. Paul, MN: Minnesota Department of Natural Resources; Wildlife Rept. No. 3. 6 p.

Inns, H. 1991. Toads on roads. Advice from the British Herpetological Society conservation committee. Country-Side. 7(8): 42-43.

Ishigaki, Kenkichi. 1987. The effects of a highway construction through the forest on avifauna. Research Bulletin of the College of Experimental Forestry, Hokkaido University. 44(2): 823-832.

Ishigaki, Kenkichi. 1987. The effects of a highway on the behaviour of birds. Research Bulletin of the College of Experimental Forestry, Hokkaido University. 44(2): 809-821.

Jackson, Jerome A. 1979. Highways and wildlife--some challenges and opportunities for management. In: Swanson, G. A., ed. The mitigation symposium: a national workshop on mitigation losses of fish and wildlife habitat; 1979 July 16-20; Fort Collins, CO. Gen. Tech. Rep. RM-65. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 566-571.

Jackson, S. 1996. Underpass systems for amphibians. In: Evink, G.; Ziegler, D.; Garrett, P; Berry, J., eds. Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors: Proceedings of the Florida Department of Transportation/Federal Highway Administration transportation-related wildlife mortality seminar; 1996 April 30-May 2; Orlando, FL. FHWA-PD-96-041. Washington, DC: U.S. Department of Transportation, Federal Highway Administration: 224-227.
Amphibian tunnels installed for spotted salamanders in Amherst, Massachusetts were successful in providing passage under a two-lane road. Of the salamanders that reached the mount of the tunnel,

75.9% passed through the tunnel that night. Lack of light seemed to deter salamander movement through the tunnel and he recommends designing the tunnels to provide substantial ambiant light (by using grates rather than slots on the top of the tunnels).

Jackson, S. D.; Tyning, T. F. 1989. Effectiveness of drift fences and tunnels for moving spotted salamanders (*Ambystoma maculatum*) under roads. In: Langton, T. E., ed. Amphibians and roads. Proceedings of the toad tunnel conference; 1989 January 7-8; Rendsburg, Federal Republic of Germany. Shefford, England: ACO Polymer Products Ltd.: 93-98.

Jackson, S. D.; Griffin, C. R. 1998. Toward a practical strategy for mitigating highway impacts on wildlife. In: Evink, G. L.; Garrett, P.; Zeigler, D.; Berry, J., eds. Proceedings of the international conference on wildlife ecology and transportation; 1998 February 10-12; Ft. Myers, FL. Tallahassee, FL: Florida Department of Transportation: 17-22.
There is evidence that animal passage systems can be designed to facilitate movement of certain wildlife species across highways. However, the effectiveness of highway mitigation systems have not been evaluated with respect to the majority of wildlife species. It is probable that some will not require specific design features while others will require careful attention to factors such as placement, size, substrate noise, temperature, light, and moisture. While it may be impractical to design each mitigation project to account for the specific requirements of all species expected to use it, it may be possible to develop a generalized strategy for making highways permeable for a large number of species. This strategy may require a variety of techniques given that the specific requirements for particular species may be contradictory. Some of the most effective techniques for facilitating wildlife movement (e.g., overpasses) also are quite expensive. A practical strategy for mitigating highway impacts on wildlife movement may dictate that expensive elements be reserved for areas that are identified and designated as important travel corridors or connections between areas of significant habitat, while inexpensive elements can be used at appropriate areas throughout the highway alignment. A practical strategy for mitigating highway impacts should first focus at the landscape level, using the most effective techniques available to maintain landscape continuity and metapopulation dynamics within designated "connectivity zones." In addition to the maintenance of some level of ecosystem function, cost effective techniques should be practically employed throughout the highway alignment to maintain local wildlife populations.

Jahn, I. R. 1959. Highway mortality as an index of deer population change. Journal of Wildlife Management. 23: 187-179.
This paper focuses on evaluating roadkill rates as an index of deer populations. Sixty-seven percent of collisions occurred in the forested northern portion of Wisconsin while 43% occurred in the agricultural southern part of the state (disproportionate to availability).

Jalkotzky, M. G.; Ross, P. I.; Nasserden, M. D. 1997. The effects of linear developments on wildlife: a review of selected scientific literature. Calgary, Alberta: Canadian Association of Petroleum Producers. 115 p.
This document reviews the scientific literature describing the effects of linear developments on wildlife, especially large mammals. Of particular interest were the types of roads and linear developments created by the oil and pipeline industries in western Canada. Subjects reviewed include the landscape functions of corridors, disturbance effects, linear development types, species/group summaries, and mitigation measures.

Jaren, V.; Andersen, R.; Ulleberg, M. and others. 1991. Moose-train collisions: the effects of vegetation removal with a cost-benefit analysis. Alces. 27: 93-99.
The number of moose killed annually in collisions along Norwegian railroads averaged about 500 in the late 1980's, representing 2% of the total annual hunting bag (25,000 moose) in the same period. However, consequences for management of local and regional moose populations can be considerable in certain areas where collisions are concentrated. In the period 1980 to 1988 a field experiment was carried out in order to test a conflict reducing method. Vegetation removal in a 20-30 m wide sector on each side of the railway line caused a 56% (+/-16%) reduction in number of train kills. The results from

the field experiment have been used in a cost-benefit analysis for the total Norwegian railroad network. If we assume that the number of collisions can be reduced by 50% as a result of vegetation removal, and calculate the cost of this treatment compared to the cost per casualty, it appears to be of positive economical benefit to treat all sections of railroad where the annual number of collisions is higher than 0.3/km. This leads to the conclusion that it is profitable to take these remedial actions along about 500 kilometers of Norwegian railroads, which will require an investment of NOK 11 million and give a net economical surplus to society of NOK 31 million (1 USD = appr. 6.5 NOK). However, it is necessary to complete the analysis with local evaluations, which must include whether the main problem on each specific railway section is really the vegetation cover.

Jayewardene, M. J. 1989. Road accidents in bird life. Loris. 18(4): 156-157.

Jefferies, D. J. 1975. Different activity patterns of male and female badgers (*Meles meles*) as shown by road mortality. London: Journal of Zoology. 177(4): 504-506.

Jefferies, D. J.; Mitchell, Jones A. 1993. Recovery plants for British mammals of conservation importance, their design and value. Mammal Review. 23: 155-166.

Jenkins, K. 1996. Texas Department of Transportation wildlife activities. In: Evink, G.; Ziegler, D.; Garrett, P.; Berry, J., eds. Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors: Proceedings of the Florida Department of Transportation/Federal Highway Administration transportation-related wildlife mortality seminar; 1996 April 30-May 2; Orlando, FL. FHWA-PD-96-041. Washington, DC: U.S. Department of Transportation, Federal Highway Administration.: 174-204.
Activities summarized include; brown pelican roadkill mitigation, bats and bridges, ocelot roadkill mitigation (using a culvert), concho water snake mitigation (altered bridge design to minimize bank disturbance), and Houston toad crossing tunnels.

Jensen, Bjarke H. 1995. A *Pelobates fuscus* population threatened by road construction. Memo. Soc. Fauna Flora Fenn. 71(3-4):146.

Jensen, D. R. 1977. The Fish Creek Highway deer passage project. Pocatello, ID: Idaho Transportation Department, District 5; Unpublished report. 13 p.
They conducted track surveys of deer movements and installed crossing structures.

Jensen, W. F.; Fuller, T. K.; Robinson, W. L. 1986. Wolf (*Canis lupus*) distribution on the Ontario-Michigan border near Sault Ste. Marie. Canadian Field Naturalist. 100: 363-366.
Wolf distribution is affected by road density.

Jessup, G. 1984. Norfolk mammal report 1983, road casualty figures. Norfolk & Norwich Naturalists Society Transactions. 6(6): 407-411.

Johnson, C. J. 1995. Method for estimating the dollar values of lost wildlife diversity and abundance resulting from wildlife-road vehicle collisions. Victoria, British Columbia: Ministry of Transportation and Highways, Planning Services Branch. [Pages unknown].
Vehicle-wildlife collisions are one of the most direct and visible negative environmental consequences of highways that bisect mobile wildlife populations. Such collisions can have significant effects on the abundance and diversity of affected wildlife populations. This paper presents a method that may be used to estimate the frequency of such collisions and calculate their corresponding dollar value. This value may then be used in the economic analysis of mitigation or alternative planning strategies. A theoretical example is presented to illustrate the information and calculations necessary to estimate the monetary costs of non-consumptive, consumptive, and preservation values resulting from road-related wildlife mortalities.

Johnson, Donald R.; Todd, Michael C. 1977. Summer use of a highway crossing by mountain caribou. Canadian Field Naturalist. 91(3): 312-314.

Johnson, William A.; Arlen, W. T. 1985. Fisher, *Martes pennanti*, behavior in proximity to human activity. Canadian Field Naturalist. 99(3): 367-369.

Jones, M. B.; Longhurst, W. M. 1958. Overhanging deer fences. Journal of Wildlife Management. 22. [Pages unknown].

Jones, P. H. 1980. Bird scavengers on Orkney roads. British Birds. 73(12): 561-568.

Joselyn, G. B. 1969. Wildlife. Essential consideration determining future highway roadside maintenance policy. Highway Research Record. 28: 1-14.
This report discusses emerging concepts of roadside vegetation management and resulting implications for ground-nesting birds and small mammals in Midwest; growing trend toward minimum mowing creates more acres of nesting cover and habitat for small birds and mammals. The author suggests research for appraisal of possible safety hazards resulting from increasing use of highway roadsides by nesting birds.

Jozsef, R. K. 1980. Cenological and ecological investigations on birds of road-side mulberry trees. Aquila. 87: 79-93.

Kaczensky, P. 1995. Bears and highways in Slovenia. International Bear News. 4: 17-22.

Kartanas, E. 1996. Breeding bird communities inhabiting vegetation belts along mid-field roads. Acta Universitatis Nicolai Copernici Biologia. 51: 93-110.
The paper presents the results of quantitative studies of breeding birds communities inhabiting the vegetation belts lining mid-field roads. It contains data on the number of species, the dominance structure, and the values of energy parameters of the communities under study. The results made it possible to determine the factors affecting the number of species and the overall density of bird communities in the belts of vegetation along mid-field roads.

Kasworm, W. F.; Manley, T. 1990. Road and trail influences on grizzly and black bears in northwest Montana. International Conference on Bear Research and Management. 8: 79-84.

Kavanagh, R. P.; Murray, M. 1996. Home range, habitat and behaviour of the masked owls (*Tyto novaehollandiae*) near Newcastle, New South Wales. Emu. 96: 250-257.
A 14 month study of a pair of masked owls (*Tyto novaehollandiae*) in a fragmented mosaic of urban bushland (dry open-forest) near Newcastle found high site-fidelity during two autumn-winter breeding seasons. The birds spent long periods of most nights during May to September 1994 and March to July 1995 in a particular patch of bushland where, by day, they roosted inside the large hollows of old eucalypts. The spectacular aerial courtship display of the male was observed on seven nights during March to July. Breeding did not occur in 1994. Courtship displays occurred earlier in the 1995 season than in 1994 but nesting had not begun by the end of the study in July 1995. The adult female was radio-tagged in September 1994 and tracked for a total of 14 weeks until December 1994. The home range of this bird was estimated as 1017 to 1178 hectares. The presumed breeding area was located on the edge of the non-breeding home range. The radio-tagged owl spent three-quarters of its time at night in bushland or within 100 meters either side of the bushland edge and the remainder more than 100 meters from any bushland. More than half (59%) of its time was spent within 100 meters of ecotones between bushland and open country (e.g., roads and fields) or between bushland and residential areas. The radio-tagged owl spent 82% of its time in, or next to, environments that had been extensively modified by man. During the non-breeding season, it roosted among the dense foliage of several introduced trees occurring on residential properties. The diet of these owls consisted mainly of

introduced species of small terrestrial mammals, particularly *Rattus rattus*, but several birds were also taken.

Keddy, Paul A.; Spavold, A. J.; Cathy, J. K. 1979. Snowmobile impact on old field and marsh vegetation in Nova Scotia, Canada: an experimental study. Environmental Management. 3(4): 409-415.

Keitt, T. H.; Urban, D. L.; Milne, B. T. 1997. Detecting critical scales in fragmented landscapes. Conservation Ecology (online). 1(1):4.
They used Mexican spotted owl habitat to look at the interaction between habitat fragmentation and dispersal distance. They demonstrate that landscape connectivity is highly scale dependent. Connectivity does not increase gradually with increasing scale, but changes abruptly as the landscape undergoes a percolation transition (in the case of Mexican spotted owls this is a dispersal distance of 45 kilometers). They predict that landscape configuration will be important to species whose dispersal behavior places them near the landscape percolation threshold.

Keller, V. E. 1991. The effect of disturbance from roads on the distribution of feeding sites of geese (*Anser brachyrhynchus*, A. *anser*), wintering in north-east Scotland. Ardea. 79: 229-232.

Keller, Verena; Bauer, Hans G.; Ley, Hans W.; Pfister, Hans P. 1996. The influence of wildlife overpasses for birds. Ornithol. Beob. 93(3): 249-258.
Information is given on the use of wildlife overpasses by birds in the Alsace region in France and in south Germany. The overpasses or "green bridges" are designed to mitigate habitat loss due to road or highway construction.

Kelsall, J. P.; Simpson, K. 1987. The impacts of highways on ungulates: a review and selected bibliography. Surrey, B.C.: Keystone Bio-Research. [Pages unknown].

Khokhlov, A. N. 1981. Bird mortality on roads. Priroda (Moscow). 981(9): 51-55.

Kiefer, Andreas; Hubert, Merz; Wolfgang, Rackow and others. 1994. Bats as traffic casualties in Germany. Bat Research News. 35(1): 28-32.

Kilbride, K. M.; Crawford, J. A.; Blakely, K. L.; Williams, B. A. 1992. Habitat use by breeding female California quail in western Oregon. Journal of Wildlife Management. 56: 85-90.
We quantified habitat use, nest site selection, and home range sizes of female California quail (*Callipepla californica*) during the breeding season because the effects of human manipulations on these variables at the time were known. We used radiotelemetry to monitor 58 hens in western Oregon from May through mid-August in 1988 (n = 31) and in 1989 (n = 27). Hens nested on roadsides more frequently (P = 0.02) than expected relative to availability and used cultivated fields less (P = 0.002) than expected. Nest sites had more (P = 0.02) bare ground and less grass (P = 0.06), shrub (P = 0.04), and vertical cover (50-75 cm) (P = 0.0005) than random locations. During four phases of the breeding season, mean home range size varied from 4 to 22 hectares and was smallest (P = 0.0003) during incubation. Habitat manipulations that promoted key quail foods also may enhance quail productivity by increasing amounts of early successional stages used as nesting cover.

King, C. M.; Flux, M.; Innes, J. G.; Fitzgerald, B. M. 1996. Population biology of small mammals in Pureora Forest Park: 1. Carnivores (*Mustela erminea, M. furo, M. nivalis*, and *Felis catus*). New Zealand Journal of Ecology. 20(2): 241-251.
The food habits and habitats occupied by four carnivores were studied in Pureora Forest Park, New Zealand. Stoats were the most plentiful and lived throughout a variety of forest types feeding on rabbits, rats, possums, and birds. Weasels lived in young plantations and along roads where there were adequate supplies of mice. Feral cats and ferrets preyed in native forests which held abundant supplies of rats and possums.

King, C. M.; Innes, J. G.; Flux, M. and others. 1996. Distribution and abundance of small mammals in relation to habitat in Pureora Forest Park. New Zealand Journal of Ecology. 20(2): 215-240.
Populations of ship rats (*Rattus rattus*), Norway rats (*R. norvegicus*), feral house mice (*Mus musculus*), stoats (*Mustela erminea*), weasels (*M. nivalis*), and ferrets (*M. furo*) were sampled with killtraps every three months from November 1982 to November 1987 in logged and unlogged native forest and in exotic plantations of various ages at Pureora Forest Park, central North Island. Mice (n=522 collected) were fewest in unlogged native forest, more abundant in road edge cutover forest, and most abundant in a young (5 to 10 years old) plantation. Traps catching most mice were set in dense ground cover under a low, sparse canopy. Ship rats (n=1793) were absent from the young plantation, present but not abundant in older exotic forest, and abundant in all native forest regardless of logging history. Traps set on warmer, steeper sites caught most ship rats, and those set in early successional habitats caught fewest. There was a marked reciprocal relationship between the distributions of ship rats and of mice: the proportion of mice in the total catch of rodents decreased significantly at the least, disturbed forest sites (P<0.001). Most (81%) Norway rats (n=43) were caught in a single trap in unlogged native forest on the bank of a stream. Stoats (n=57) were most abundant in the older exotic plantations; weasels (n=16) in the young plantation and along road edges in native forest; and ferrets (n=11) in unlogged native forest. Hedgehogs (n=290) were common in unlogged native forest far from any roads and also in older exotic forest. Our data suggest that selective logging and conversion to exotics have different effects on each of the six species we monitored. We hypothesize that (1) selective logging is likely to stimulate temporary increases in the numbers of mice and weasels, but not rats or stoats, and (2) after conversion to exotic forest, mice and occasionally weasels will be abundant at first but will gradually be replaced by ship rats and stoats as the forest matures.

Kinnear, P. K. 1978. Common and black-headed gulls feeding on road corpses. British Birds. 71(2): 80-85.

Kjensmo, J. 1997. The influence of road salts on the salinity and the meromictic stability of Lake Svinsjoen, southeastern Norway. Hydrobiologia. 347: 151-158.
Primarily as a result of road salting, the water masses of Lake Svinsjoen, a small meromictic lake in southeastern Norway, have been subject to great changes in salinity during the period 1947-1995. The greatest change in salt concentration has occurred in the upper part of the monimolimnion (depth 10-15 m) where mean conductivity increased 104.2%, from 143 to 292 mu S cm(-1). In the upper mixolimnion (depth 0-5 m), mean conductivity rose from 130 to 238 mu S cm(-1) during the same period. The ions responsible for the salinity changes were Naf and Cl- from de-icing salts, and Ca2+ and Cl- from salts used to keep down dust from roads. Further sources of Ca2+ are the road asphalt and increased weathering and leaching of the lime-rich rocks caused by acid precipitation, the main source of the additional inputs of SO42- to the lake. The salinity changes caused major changes in meromictic stability, S-c'. In the period 1947-1966, S-c' increased by 24 g-cm cm(-2), and the maximum level of meromictic stability, 125 mu g cm(-2), was found in 1966. As a result of higher rate of salt accumulation in the upper part of the monimolimnion and in the mixolimnion, S-c' decreased by 30 g-cm cm(-2) during the period 1966-1991, and a simultaneous rise in the chemocline took place. In the period 1991-1995 an additional decrease of 26 g-cm cm(-2) occurred. Continued ectogenic inputs of salts through processes typical of the time period investigated will in future further weaken the lake's meromictic stability, and may cause the demise of meromixis in Lake Svinsjoen, a development which may have important implications for primary productivity of the lake.

Klein, D. R. 1971. Reaction of reindeer to obstructions and disturbances. Science. 173: 393-398.

Klenavic, J. S. 1979. Banff highway project (east gate to Km 13). [Location of publisher unknown]: Federal Environmental Assessment and Review Office. [Pages unknown].; (FEARO) report.

Kline, N. C.; Swann, D. E. 1998. Quantifying wildlife road mortality in Saguaro National Park. In: Evink, G. L.; Garrett, P.; Zeigler, D.; Berry, J., eds. Proceedings of the international conference on wildlife ecology and transportation; 1998 February 10-12; Ft. Myers, FL. Tallahassee, FL: Florida Department of Transportation: 23-31.

Roadkill is undoubtedly the greatest human-caused source of direct mortality to vertebrate animals in many parks and reserves, yet its overall impact remains poorly documented. To begin to quantify the effects of roadways on wildlife in Saguaro National Park, Arizona, park staff initiated regular roadkill surveys in January, 1994. These surveys have documented 2,030 wildlife road mortalities during a three-year period, and have enabled managers to identify specific areas and taxa of concern. Nevertheless, the number of individual animals observed are clearly only a small fraction of the number killed on roads in and adjacent to the park. To calculate a more accurate estimate of total annual road mortality, we conducted studies to determine the effect of stochastic, short-term weather events; the length of time carcasses persist on roadways; and the observer error associated with our studies. Preliminary results of these studies provide what we consider a very conservative estimate of 7,155 vertebrates killed on park through- and boundary-roads annually. This paper presents results of our roadkill surveys to date and discusses their implications towards wildlife management in protected areas near increasing external development.

Kline, P. D. 1965. Factors influencing roadside counts of cottontails. Journal of Wildlife Management. 29(4): 665-670.
The author found that rabbit counts along roads peaked in July and February. He suggests that rabbits are attracted to roads during July because the surfaces are warmed and dried by solar radiation. Rabbits counts are higher along roads in February because rabbits are easier to detect in snow and they tend to be concentrated around favorable roadside vegetation during deep snow conditions.

Knight, R. L.; Kawashima, J. Y. 1993. Response of raven and red-tailed hawk populations to linear right-of-ways. Journal of Wildlife Management. 57: 266-271.
Linear right-of-ways are ubiquitous in the United States and may alter vertebrate populations, yet they remain little studied. We examined the relationship between these areas and common raven (*Corvus corax*) and red-tailed hawk (*Buteo jamaicensis*) populations in the Mojave Desert of California by flying helicopter transects along paved highways, transmission powerlines, and control areas (i.e., no highways nor powerlines within 3.2 km). Ravens were equally ($P > 0.10$) common along highway and powerline transects, but were more ($P < 0.02$) abundant along these transects than along controls. Raven nests were more ($P < 0.0001$) abundant along powerlines than along either highways or controls. Red-tailed hawks and their nests were more ($P < 0.0001$) abundant along powerlines than along either highway or control transects. Neither species used potential nest or perch sites in proportion to their availability. Ravens used power poles as nest sites more ($P < 0.001$) than expected based on availability, but not ($P > 0.10$) as perch sites. Red-tailed hawks used power poles for both nesting and perching more ($P < 0.001$) than expected based on availability. Our data suggest that ravens are more abundant along highways because of automobile-generated carrion, whereas both ravens and red-tailed hawks are more common along powerlines because of the presence of superior perch and nest sites. We recommend that land managers evaluate possible changes in vertebrate populations and community-level interactions when assessing the effects of future linear fight-of-way projects.

Knight, R. L.; Knight, HA L.; Camp, R. J. 1995. Common ravens and number and type of linear rights-of-way. Biological Conservation. 74(1): 65-67.
We counted common ravens (*Corvus corax*) during 1990 and 1991 in the Mojave Desert, California, to examine hypotheses relating to number and type of linear rights-of-way. First, we hypothesized that raven numbers would increase with increasing in road traffic volume and traffic speed. Second, we hypothesized that raven numbers would show a positive relationship with increasing number of linear rights-of-way which ran in parallel. Our data did not support the first hypothesis but did support the second.

Knoblach, W. 1939. Death on the highway. Journal of Mammalogy. 20: 508-509.

Knutson, R. M. 1987. Flattened fauna. A field guide to common animals of roads, streets, and highways. Berkeley, CA: Ten Speed Press. 127 p.

Knzig, J. 1995. No to motorway plan. Naturopa. No. 79: 27-30.
Construction of a road through a migratory bird reserve was stopped by the Bern Convention. The plan is now to tunnel beneath the reserve.

Koehne, J. L. 1991. Wildlife-related traffic accidents: a comparison of existing and proposed mitigation measures. Seattle, WA: University of Washington. 39 p.
Classifies mitigation measures as those that 1) keep wildlife away from the road, 2) increase the driver's ability to prevent an accident should wildlife enter the road, 3) improve the driver's awareness of the danger posed by wildlife. Discusses increasing roadside vegetation clearance to improve visibility. Recommends use of chemical repellants (wolfin), improved vehicle lighting, and signing as mitigation measures.

Kolodenko, A. I. 1981. On the mortality of reptiles and amphibians by vehicles on the roads of Turkmenistan. In: Darevskij, I. S.; Ananeva, N. B.; Barkagan, Z. S. and others, editors. eds. The problems of herpetology: abstracts. Leningrad: Nauka: 68-68.

Korbel, O. 1995. Hindering otter (*Lutra lutra*) road kills. Part 2. IUCN Otter Specialist Group Bulletin. 1: 40-47.

Korn, H. 1987. Sequential life-trapping and snap-trapping of rodents on a wooded island surrounded by roads. Saeugetierkundliche Mitteilungen. 3(1): 74-78.

Korn, H. 1992. Rapid repopulation by small mammals of an area isolated by roads. Mammalia. 5(4): 629-632.

Korn, H. 1993. Detecting small mammal movements across roads with the aid of coloured bait. Zeitschrift Fuer Angewandte Zoologie. 79(3): 371-376.
Road crossings of small mammals were observed by means of a tracking method. The applicability of the method was tested on four different sized roads in two different years. Road crossings of woodland rodents were common which shows that commonly used live trapping methods may underestimate movements across such barriers. No pattern was found concerning road width or daytime traffic volume. Advantages, limitations, and further possible applications of the method are discussed.

Kostelecka-Myrcha, Alina; Zukowski, Jan; Oksiejczuk, Elzbieta. 1997. Changes in the red blood indices during nestling development of the tree sparrow (*Passer montanus*) in an urban environment. Ibis. 139(1): 92-96.
The authors describe their study to determine the effects of lead pollution on hematological parameters of tree sparrow nestlings in the vicinity of roads and intersections in Poland.

Kozel, R. M.; Fleharty, E. D. 1979. Movements of rodents across roads. Southwestern Naturalist. 24: 239-248.

Kratky, J. 1995. Vertebrate casualties on the roads of the Middle Elbe lowlands. Casopis Narodniho Muzea Rada Prirodovedna. 164(1-4): 91-97.
A study on the influence of the traffic on Nymburk district's roads (Middle Elbe lowlands) on vertebrate road mortality was performed. 181 carcasses i.e. 7.6 vertebrates killed per 100 kilometer were found on a 3.5 kilometer road section, the breakdown of them found 61.3% mammals, 35.9% birds and 2.8% reptiles and amphibians. Taxa *Apodemus* sp., *Erinaceus* sp., *Microtus arvalis* and *Lepus europaeus* were mostly found. The highest number of findings occurred in July, the smallest one in February. It was found that the number of animals killed on the roads over a 3-year period decreased year-by-year.

Krikowski, L. 1989. The 'light and dark zones': two examples of tunnel and fence systems. In: Langton, T. E. S., ed. Amphibians and roads. Proceedings of the toad tunnel conference; 1989 January 7-8; Rendsburg, Federal Republic of Germany. Shefford, England: ACO Polymer Products Ltd.: 89-91.

Krivda, W. 1993. Road kills of migrating garter snakes at The Pas, Manitoba. Blue Jay. 51(4): 197-198.

Kruger, H. H.; Wolfel, H. 1991. Behavioral response of fallow deer to various types of simulated underpasses. Godollo, Hungary: XXth Congress of the International Union of Game Biologists 597 p.
This study evaluates the behavioral response of fallow deer to different designs of simulated box underpasses. In a 0.5 ha pen, five different types of tunnel design were tested. Tests of preference were made by the two-choice method. Light-grey painted underpasses were used significantly ($P<0.04$) more often as compared with black or dark-grey underpasses. The number of passages through a tunnel with tree stems in it, was not greater ($P>0.11$) than those without stems. An artificial illuminated tunnel was significantly avoided ($P<0.01$).

Kruuk, H.; Conroy, J. W. 1991. Mortality of otters (*Lutra lutra*) in Shetland. Journal of Applied Ecology. 28(1): 83-94.

Kuennen, T. 1989. New Jersey's I-78 preserves mountain habitat. Roads and Bridges. February: 69-73.
A 6-lane sunken highway was built along a park including two overpasses used by deer and recreationists.

Kurosawa, Reiko. 1994. Bird abundance in relation to the pavement rate of Tokyo. Strix. 13: 155-164.

Kusak, J.; Huber, D.; Frkovic, A. 1998. Large carnivores and traffic kills in Croatia. Journal of Wildlife Conservation.

Kussy, Edward V. 1982. Wetland and floodplain protection and the federal-aid highway program. Environmental Law. 13(1): 161-264.

Lalo, J. 1987. The problem of roadkill. American Forests. Sept./Oct.: 50-53.

Land, D.; Lotz, M. 1996. Wildlife crossing designs and use by Florida panthers and other wildlife in southwest Florida. In: Evink, G.; Ziegler, D.; Garrett, P; Berry, J., eds. Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors: Proceedings of the Florida Department of Transportation/Federal Highway Administration transportation-related wildlife mortality seminar; 1996 April 30-May 2; Orlando, FL. FHWA-PD-96-041. Washington, DC: U.S. Department of Transportation, Federal Highway Administration: 323-328.
Roadkill consisted of 20.5% of documented panther mortality. Previous roadkill locations and telemetry locations were used to identify places for 24 wildlife underpasses when I-75 was constructed. Trailmaster camera sets and tracking surfaces were used to monitor wildlife use of the underpasses. Bobcat, deer, panther, alligator, raccoon, turkey, fox, and otter were detected using the underpasses. Panther use of underpasses was higher than reported by Foster and Humphrey 1995, and may reflect greater acceptance of underpasses as individuals gained experience in crossing. In general, the crossings have been very successful. The location of the crossing is probably more important than the design.

Langenau, E. E.; Rabe, M. L. 1987. Deer-vehicle accidents in Michigan: a task force report. Lansing, MI: Michigan Department of Natural Resources, Wildlife Division; Wildlife Div. Report No. 3072. 46 p.
In 1986, 34,252 collisions cost $75 million and resulted in 1,469 injuries and five deaths. Evaluates characteristics of collision locations and mitigation recommendations.

Langton, T. E. S. 1989. Amphibians and roads: proceedings of the toad tunnel conference; 1989 January 7-8; Rendsburg, Federal Republic of Germany. Shefford, England: ACO Polymer Products Ltd. 202 p.

Langton, T. E. S. 1989. Reason for preventing amphibian mortality on roads. In: Langton, T. E. S., ed. Proceedings of the Toad Tunnel Conference; 1989 January 7-8; Rendsburg, Federal Republic of Germany. Shefford, England: ACO Polymer Products Ltd.: 75-80.

Langton, T. E. S. 1989. Tunnels and temperature: results from a study of a drift fence and tunnel system for amphibians at Henly-on-Thames, Buckinghamshire, England. In: Langton, T. E., ed. Proceedings of the Toad Tunnel Conference; 1989 January 7-8; Rendsburg, Federal Republic of Germany. Shefford, England: ACO Polymer Products Ltd.: 145-152.

Lathrop, E. W. 1983. The effect of vehicle use on desert vegetation. In: Webb, R. H.; Wilshire, H. G., eds. Environmental effects of off-road vehicles: impacts and management in arid regions. New York: Springer-Verlag: 153-166.

Laursen, K. 1981. Birds on roadside verges and the effect of mowing on frequency and distribution. Biological Conservation. 20: 59-68.

Lavsund, S.; Sandgren, F. 1991. Moose-vehicle relations in Sweden: a review. Alces. 27: 118-126.
Provides a review of moose vehicle collisions in Sweden, including accident rates, seasonality, contributing factors, and mitigation.

Leach, G. J.; Recher, H. F. 1993. Use of roadside remnants of softwood scrub vegetation by birds in south-eastern Queensland. Wildlife Research. 20(2): 233-249.
Birds in roadside and remnant patches of vegetation in the Marburg district of south-eastern Queensland were studied from November 1989 to February 1990. Effects of the length, width and height of the tree, shrub and herb layers, and their major components, on the bird community were determined. In all, 43 species of birds were observed in roadside vegetation; 16 of these were abundant and widely distributed. Silvereyes were most frequently observed (240 observations), followed by superb fairy-wrens (59), yellow thornbills (53), double-barred finches (26), red-backed fairy-wrens (25) and Lewin's honeyeaters (20). Apart from silvereyes (20-65% of observations), and superb fairy-wrens on two roads (12 and 13%) and yellow thornbills on one (15%), no other species constituted more than 10% of observations on any road. In all, 48 species of birds were observed in remnant patches of vegetation, 14 in all of them. Rates of detection in remnant patches ranged from 2.7 to 5.3 birds per 5 minutes compared with a mean maximum rate for roadside vegetation of 1.3. The richness of the roadside avifauna increased significantly (P=0.001) as the volume (length x width x height) of the tree component, especially the softwood species, increased. The diversity of tree species in softwood remnants and the greater canopy density appear to be important factors that enhance the bird community. Some simple management practices, such as maintaining a minimum width of undisturbed vegetation and retaining vegetation diversity, would ensure or enhance the long-term conservation benefits. Opportunities to regenerate softwood remnants could also be taken, particularly to enhance the value, and possibly prolong the life, of the associated remnants of brigalow.

LeBlanc, R. 1994. Small mammal use of culverts along the Trans-Canada Highway (Phase III), Banff National Park. Banff, Alberta: Parks Canada, Banff National Park Warden Service. 22 p.
Existing culverts and bridges along a portion of the Trans-Canada Highway, most not designed for wildlife passage, were monitored for small mammal crossing use. Monitoring was based on winter snow tracking. Species documented using culverts or bridges to cross under the highway included weasel, squirrel, coyote, marten, and elk. The most important factors influencing the use of culverts for crossing were the presence of forest cover near the culvert entrance, and the depth of the culvert entrance below the highway surface. These factors determined the level of sight and auditory disturbance at the culvert entrance.

Leedy, D. L. 1975. Highway-wildlife relationships, Vol. 1. A state of the art report. Washington, DC: U.S. Department of Transportation, Federal Highway Administration; FHWA-RD-76-4. 183 p.
The study assesses, primarily through an extensive literature review, what is known about highway-wildlife relationships and suggests research and management approaches to protect and enhance fish, wildlife, and environmental quality. The 20 million or more acres in highway rights-of-way have been largely neglected as wildlife habitat. Opportunities exist for creating valuable fish and wildlife impoundments during construction, yet the minimal effort needed to locate and design such

impoundments has generally not been made. The Nation's four million miles of streets and highway often create 'edges' conducive to wildlife. Many millions of wild vertebrates are killed annually, but apparently most wildlife populations are not seriously affected by such losses. Highway construction through limited ranges of endangered species can be a serious problem, as can erosion, wetland drainage, stream alteration, structures which block the passage of anadromous fish, and pollutants resulting from highway maintenance and use. Better measures for mitigating habitat losses, predicting effects of highways on fish and wildlife, reducing animal-vehicle accidents, and enhancing highway environment for fish, wildlife, and people are sorely needed.

Leedy, D. L. 1975. Highway-wildlife relationships, Vol 2. An annotated bibliography. Washington, DC: U.S. Department of Transportation, Federal Highway Administration; FHWA-RD-76-5. 417 p.
The study assesses, primarily through an extensive literature review, what is known about highway-wildlife relationships and suggests research and management approaches to protect and enhance fish, wildlife, and environmental quality. The 20 million or more acres in highway rights-of-way have been largely neglected as wildlife habitat. Opportunities exist for creating valuable fish and wildlife impoundments during construction, yet the minimal effort needed to locate and design such impoundments has generally not been made. The Nation's four million miles of streets and highway often create 'edges' conducive to wildlife. Many millions of wild vertebrates are killed annually, but apparently most wildlife populations are not seriously affected by such losses. Highway construction through limited ranges of endangered species can be a serious problem, as can erosion, wetland drainage, stream alteration, structures which block the passage of anadromous fish, and pollutants resulting from highway maintenance and use. Volume 2 contains 794 references.

Leedy, D. L.; Maestro, R. M.; Franklin, T. M. 1978. Planning for wildlife in cities and suburbs. Ellicott City, MD: Urban Wildlife Research Center, Inc.; FWS/OBS77/66. 77 p. Sponsored by: Fish and Wildlife Service, Washington, D.C.
This manual brings together two disciplines--wildlife management and urban planning--that have had little to do with each other. Opportunities for wildlife enhancement are discussed in relation to site design, urban core areas, suburbs and new towns. The importance of habitat diversity is stressed. Sources of additional information and assistance, lists of plants valuable to wildlife, and recommended reading materials are provided in appendices.

Leedy, D. L.; Adams, L. W. 1982. Wildlife considerations in planning and managing highway corridors. Washington, DC: U.S. Department of Transportation, Federal Highway Administration; FHWA-TS-82-212. [Pages unknown].
The manual serves as a guide and information source for biologists, environmental specialists, and highway personnel concerned with route selection, design, construction, operation, and maintenance of the Nation's highways. The manual serves as an information source on highway-wildlife relationships and effects; provides information sources and 'how to' guidance for inventorying wildlife populations, assessing environmental impacts, and evaluating habitat; suggests ways of incorporating wildlife values into highway planning; and offers suggestions for managing wildlife populations within the highway right-of-way. The manual is organized to facilitate location of specific topics.

Leeson, B. 1996. Highway conflicts and resolutions in Banff National Park, Alberta. In: Evink, G.; Ziegler, D.; Garrett, P.; Berry, J., eds. Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors: Proceedings of the Florida Department of Transportation/Federal Highway Administration transportation-related wildlife mortality seminar; 1996 April 30-May 2; Orlando, FL. FHWA-PD-96-041. Washington, DC: U.S. Department of Transportation, Federal Highway Administration: 80-84.
The author summarizes an elk study and justification of mitigation measures. Elk have been using underpasses extensively. The report describes two 50-meter wide wildlife overpasses that are under construction.

Leeson, B. 1998. Bridging the Rockies - Banff's roadway for wildlife. In: Evink, G. L.; Garrett, P.; Zeigler, D.; Berry, J., eds. Proceedings of the international conference on wildlife ecology and transportation; 1998 February 10-12; Ft. Myers, FL. Tallahassee, FL: Florida Department of Transportation: 120-121.
This paper reports on the success of mitigation measures to enhance wildlife survival and habitat connectivity in the twinning of the Trans-Canada Highway.

Lehnert, M. E. 1996. Mule deer-highway mortality in northeastern Utah: an analysis of population level impacts and a new mitigative system. Logan, UT: Utah State University. [Pages unknown]. M.S. thesis.

Lehnert, M. E.; Romin, L.; Bissonette, J. A. 1996. Mule deer and highway mortality in northeastern Utah: causes, patterns, and a new mitigative technique. In: Evink, G.; Ziegler, D.; Garrett, P.; Berry, J., eds. Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors: Proceedings of the Florida Department of Transportation/Federal Highway Administration transportation-related wildlife mortality seminar; 1996 April 30-May 2; Orlando, FL. FHWA-PD-96-041. Washington, DC: U.S. Department of Transportation, Federal Highway Administration: 101-107.
This paper describes a highway crosswalk systems installed for mule deer near Park City. Crosswalks are a combination of drift fences and visual queues, and have had mixed success.

Leighton, D. 1988. Helping the animals cross the road. Canadian Geographic Journal. 108: 22-28.

Leimgruber, P.; McShea, W. J.; Schnell, G. D. 1996. Changes in forest composition and bird communities with distance from roads. Bulletin Of The Ecological Society Of America. 77(3/2): 1-259.

Lepschi, B. J. 1992. Birds killed on a primary road in southern New South Wales. Corella. 16(3): 75-77.

Lewis, Adrian D. 1989. Road-kills and other records of mainly smaller mammals from Kenya: data for a Kenyan mammal atlas. EANHS (East African Natural History Society) Bulletin. 19(2): 20-22.

Lill, K.; Grabow, K.; Wimmer, W. 1997. *Monacha cartusiana* (O.F. Mueller 1774) in southeast Lower Saxony (Gastropoda: Hygromiidae). Mitteilungen Der Deutschen Malakozoologischen Gesellschaft. 59: 19-24.
Monacha cartusiana as a synanthropic species is reported from seven localities in SE Lower-Saxony, Germany. The importance of manmade linear surface-structures like highways, railways and canals as ways for spreading is evident. Habitats in Lower-Saxony are highly connected with human activities: embankments of canals and roads, scarce covered wasteland in industrial areas and near disposal sites (soil, waste).

Lindenmayer, D. B.; Cunningham, R. B.; Donnelly, C. F. and others. 1994. Factors influencing the occurrence of mammals in retained linear strips (wildlife corridors) and contiguous stands of montane ash forest in the central highlands of Victoria, southeastern Australia. Forest Ecology and Management. 67(1-3): 113-133.
Hairtubing was used to census mammals at 70 sites in 53-year-old mountain ash (*Eucalyptus regnans*) and alpine ash (*Eucalyptus delegatensis*) forest in the Central Highlands of Victoria, southeastern Australia. A total of 40 sites was located in linear strips or wildlife corridors that were retained in timber production areas. The remaining 30 sites were in stands where the adjacent forest had not been logged. Thirteen species of mammals were detected in the hairtubing surveys, but only three were detected frequently enough to allow detailed analysis. Detailed statistical analyses of the data were conducted at two levels: the site level, and for individual hairtubing plots. Logit regression models were used to explore the relationships between: (1) the probability of detecting brown antechinus (*Antechinus stuartii*), bush rat (*Rattus fuscipes*) and swamp wallaby (*Wallabia bicolor*) and the measured dimensions (e.g., width and length), environmental attributes and vegetation structure of retained linear strips; (2) the probability of occurrence of *Antechinus stuartii, Wallabia bicolor* and *R. fuscipes* in hairtubing plots within areas of contiguous forest and retained linear strips and the characteristics of the vegetation structure and plant species composition in a 10-meter area surrounding such plots.

Analyses of the combined data for the two types of sites indicated that *Wallabia bicolor* was more likely to be detected in plots within *E. regnans* forest and where there was a limited cover of ferns on the forest floor. These findings imply a degree of partitioning of the use of the forest environment by *Antechinus stuartii* and *R. fuscipes*. They also suggest that patterns of microhabitat use by some species of mammals may change when areas of montane ash forest are confined to a linear configuration (i.e., a retained strip).

Ling, R. W.; VanAmberg, J. P.; Werner, J. K. 1986. Pond acidity and its relationship to larval development of *Ambystoma maculatum* and *Rana sylvatica* in Upper Michigan. Journal of Herpetology. 20: 230-236.

Linsdale, J. M. 1929. Roadways as they affect bird life. Condor. 31: 143-145.

Little, C. E. 1990. Greenways for America. Baltimore, MD: Johns Hopkins University Press. [Pages unknown]. 288 p.

Livezek, K. B. 1991. Home range habitat use disturbance and mortality of Columbian black-tailed deer in Mendocino National Forest. California Fish and Game. 77: 201-209.
Sixteen female Columbian black-tailed deer (*Odocoileus hemionus columbianus*) were radio-collared in Mendocino National Forest, California (USA). Deer were located or observed from 29 March 1986 to 19 August 1988. Movements and home ranges of deer were classified into three descriptive groups: nonmigratory deer, migratory deer that travelled 3 to 8 kilometers between summer and winter ranges, and migratory deer that travelled 12 to 27 kilometers between seasonal ranges. Daytime use of habitats by deer was more than expected in Montane Hardwood and Annual Grassland habitats. Collared deer differed in their individual use of riparian and Montane Hardwood habitats, and used the same areas during fawning each year. Increased vehicular traffic during the hunting season apparently caused displacement of study deer whose usual home ranges during that time of year were within 200 meters of secondary roads.

Lizana, Avia M. 1992. Provisional report of the mortality of vertebrates on the roads of Salamanca Province, with isolated data from Sierra Gredos and Zamora Province, September 1991. In: Lopez, Redondo, ed. I jornadas para el estudio y prevencion de la mortalidad de vertebrados en carreteras, Madrid, 5 y 6 de Octubre de 1991. Tomo 2. [Sessions in the study of prevention of road mortalities of vertebrates, Madrid, 5 and 6 October, 1991. Volume 2.]. Ambiental, Madrid: Coordinadora de Organizacciones de Defensa: 115-117.

Lizana, M. 1993. Mortality of amphibians and reptiles on highways: report of the study AHE-CODA. Boletin De La Asociacion Herpetologica Espanola. 1993: 37-41.

LoBuono, L. P. 1988. Alligator alley: protecting natural habitat. Journal of the Florida Engineering Society. February: 14-16.

Logan, T.; Evink, G. 1985. Safer travel for the Florida panther. Florida Naturalist. 58(1): 6-7.

Loos, G.; Kerlinger, P. 1993. Road mortality of saw-whet and screech-owls on the Cape May Peninsula. Journal of Raptor Research. 27: 210-213.
During a 10 year study in southern New Jersey, 250 road-killed raptors of six owl and six hawk species were found during 145 kilometers of road travel between mid-October and early April. Northern Saw-whet Owls and Eastern Screech-Owls accounted for 45% (N = 114) and 36% (N = 91) of all road kills, respectively. More than 87% of road-killed saw-whet owls and 71% of eastern screech owls were found between November and January. We conclude that southern New Jersey, especially the southern Cape May peninsula, hosts a large number of wintering and migrating saw-whet owls and resident screech-owls, and that collisions with automobiles kill a significant number of these owls.

Lopez, Fern. 1992. Provisional report of the mortality of vertebrates on various coastal roads of Huelva, September 1991. In: Lopez, Redondo, ed. I jornadas para el estudio y prevencion de la mortalidad de vertebrados en carreteras, Madrid, 5 y 6 de Octubre de 1991. Tomo 2. [Sessions in the study of prevention of road mortalities of vertebrates, Madrid, 5 and 6 October, 1991. Volume 2.]. Ambiental, Madrid: Coordinadora de Organizacciones de Defensa: 88-96.

Lopez, Redondo J.; Lopez, Fern. 1992. Provisional results of the continuing mortality of chameleons (*Chamaeleo chamaeleon*) on the roads of Cadiz, Malaga and Huelva. In: Lopez, Redondo, ed. I jornadas para el estudio y prevencion de la mortalidad de vertebrados en carreteras, Madrid, 5 y 6 de Octubre de 1991. Tomo 2. [Sessions in the study of prevention of road mortalities of vertebrates, Madrid, 5 and 6 October, 1991. Volume 2.]. Ambiental, Madrid: Coordinadora de Organizacciones de Defensa: 267-279.

Lopez, Redondo J. 1992. Historical perspective of studies on the environmental impact of roads on vertebrates. In: Lopez, Redondo, ed. I jornadas para el estudio y prevencion de la mortalidad de vertebrados en carreteras, Madrid, 5 y 6 de Octubre de 1991. Tomo 2. [Sessions in the study of prevention of road mortalities of vertebrates, Madrid, 5 and 6 October, 1991. Volume 2.]. Ambiental, Madrid: Coordinadora de Organizacciones de Defensa: 6-10.

Lopez, Redondo J. 1992. Provisional report of the mortality of vertebrates on the roads of Madrid Province, September 1991. In: Lopez, Redondo, ed. I jornadas para el estudio y prevencion de la mortalidad de vertebrados en carreteras, Madrid, 5 y 6 de Octubre de 1991. Tomo 2. [Sessions in the study of prevention of road mortalities of vertebrates, Madrid, 5 and 6 October, 1991. Volume 2.]. Ambiental, Madrid: Coordinadora de Organizacciones de Defensa: 168-179.

Loughry, W. J.; McDonough, Colleen M. 1996. Are road kills valid indicators of armadillo population structure? American Midland Naturalist. 135(1): 53-59.
Dasypus novemcinctus in Florida.

Lovallo, M. J.; Anderson, E. M. 1996. Bobcat movements and home ranges relative to roads in Wisconsin. Wildlife Society Bulletin. 24(1): 71-76.
Our data suggest that bobcats in northwestern Wisconsin selected home ranges with relatively higher densities of trails and lower densities of secondary highways. Within established home ranges, bobcats crossed secondary highways, unpaved roads, and trails in proportion to their occurrence and crossed paved roads less than expected. Geographic and behavioral selection appeared to be a function of vehicle traffic levels and juxtaposition of preferred bobcat habitat to road types. In general, areas less than or equal to 100 m from roads contained less preferred bobcat habitat than roadless areas.

Luckenbach, Roger A. 1978. An analysis of off-road vehicle use on desert avifaunas. Transactions of the North American Wildlife Natural Resource Conference. 43: 157-162.

Luckenbach, Roger A.; Bury, R. B. 1983. Effects of off-road vehicles on the biota of the Algodones Dunes, Imperial County, California. Journal of Applied Ecology. 20(1): 265-286.

Ludwig, J.; Bremicker, T. 1981. Evaluation of 2.4 meter fences and one-way gates for reducing deer-vehicle collisions. Minnesota Wildlife Research Quarterly. 41(4): 77-88.

Lutz, Walburga. 1994. Trial results of the use of a "Duftzaun" (scent fence) to prevent game losses due to traffic accidents. Zeitschrift fuer Jagdwissenschaft. 40(2): 91-108.

Luukkainen, H. 1989. Animal subways - views of an animal protectionist and green politician. In: Langton, T. E. S., ed. Amphibians and roads. Proceedings of the toad tunnel conference; 1989 January 7-8; Rendsburg, Federal Republic of Germany. Shefford, England: ACO Polymer Products Ltd.: 81-84.

Lyon, L. J. 1983. Road density models describing habitat effectiveness for elk. Journal of Forestry. 81: 592-595.

Lyon, J. L.; Lonner, T. N.; Weigand, J. P. and others. 1985. Coordinating elk and timber management: final report of the Montana cooperative elk-logging study, 1970-1985. Bozeman, MT: Montana Department of Fish, Wildlife, and Parks; MT W-120-R. 53 p.
Final report of the Montana Cooperative elk-logging study 1970-1985.

Macdonald, L. A. 1998. Citizen participation in transportation planning--the habitat for bears campaign. In: Evink, G. L.; Garrett, P.; Zeigler, D.; Berry, J., eds. Proceedings of the international conference on wildlife ecology and transportation; 1998 February 10-12; Ft. Myers, FL. Tallahassee, FL: Florida Department of Transportation: 229-233.
This paper outlines some of the tools, from statutory provisions to grassroots organizing, that are available to the citizen who wants to participate in transportation planning and specific road projects in the state of Florida. Section one described the "Habitat for Bears Campaign" and the campaign's work to protect the Florida black bear and wildlife habitat from adverse impacts of roads, and to improve upon existing conditions where wildlife crossings or retrofitting of old road and bridges are needed. Section two gives brief summaries of the major laws and oversight bodies that provide an opportunity for the citizen to influence the transportation planning process. While this outline attempts to be comprehensive by addressing the federal, state, and local levels, it is not an exhaustive list. The last section relates some of the institutional, bureaucratic, legal, and scientific challenges to the more effective consideration of wildlife in highway planning.

Mace, R. D.; Waller, J. S. 1996. Grizzly bear distribution and human conflicts in Jewel Basin hiking area, Swan Mountains, Montana. Wildlife Society Bulletin. 24: 461-467.
Telemetry data obtained from grizzly bears (*Ursus arctos horribilis*) were used to evaluate resource selection within the Jewel Basin Hiking Area (JBHA) of western Montana. Logistic regression models were constructed using Geographic Information System maps of elevation zones, dominant cover types, and distance to hiking trails and lakes. Fourteen radiocollared grizzly bears used the JBHA between 1987 and 1994 primarily during summer. Using univariate statistics, we determined that grizzly bears were significantly farther than expected from trails and from lakes with campsites during spring, summer, and autumn. In multivariate models however, distance to trails and lakes were significant variables only during summer and autumn. During these two seasons the relative probability of grizzly bear use increased as distances to trails and lakes with campsites increased. For each season, grizzly bears selected relatively open habitats compared to the predominant forest habitat type in which most of the trail system occurred. We found no historical records of conflicts between grizzly bears and recreationists in the JBHA; bears did not appear to be conditioned to or habituated to food. No radiocollared bears lived solely within the JBHA; each individual's home range included multiple-use lands with roads and where many human activities occurred. We concluded that several factors together precluded human-bear conflicts in the JBHA. These included low visitor-use levels, trail placement, an educated public, and the bears' negative conditioning towards a host of human activities occurring within and outside the area. Therefore, while in the JBHA, grizzly bears minimized their interaction with recreationists by avoiding high-use areas.

Mace, R. D.; Waller, J. S.; Manley, T. L. and others. 1996. Relationships among grizzly bears, roads and habitat in the Swan Mountains, Montana. Journal of Applied Ecology. 33(6): 1395-1404.
Relationships between grizzly bears, habitat, and roads were investigated between 1990 and 1994 in the Swan Mountains, Montana. Relationships were examined at three levels of resource selection. Differences existed between habitat and road features within, and those outside, the multi-year composite female grizzly bear home range. Using logistic regression, large resource selection probability functions were obtained for the subalpine zone within multiple-use lands having no roads. Selection probability was zero for private lands and declined as total road density increased. Within seasonal ranges, most grizzly bears favoured low temperate and temperate elevation zones over the subalpine zone during all seasons. Relative to forested habitats, avalanche chutes were positively selected for during all seasons, but especially in spring. Shrub lands and cutting units were important

to most bears during summer and autumn. Grizzly bears were more closely associated with higher total road densities during spring than during other seasons. When in low temperate habitats, most bears used habitats with lower total road density than occurred randomly. Seasonal use by grizzly bears of areas within a 0.5 kilometer buffer surrounding roads was evaluated. Most grizzly bears exhibited either neutral or positive selection for buffers surrounding closed roads and roads receiving <10 vehicles per day but avoided buffers surrounding roads having >10 vehicles per day. Between 1988 and 1994, eight grizzly bears were killed by humans. These deaths were directly influenced by road access and unnatural food sources. These deaths, in addition to natural mortality, were too great to promote local population growth.

Mace, R. U. 1974. Application of vehicle restrictions in wildlife management. Proceedings of the Western Association of State Game and Fish Commissions. 54: 205-210.

Mader, H. J. 1984. Animal habitat isolation by roads and agricultural fields. Biological Conservation. 29: 81-96.
Natural areas are continuously disappearing. Surviving patches resemble islands in terms of limited area, isolation and distance from each other. Road construction and agricultural activities contribute to habitat isolation. Field studies suggest that roads represent barriers and cut off the gene flow by dividing animal populations into fractions on either side of the road. Several mobility diagrams show significant isolation effects of roads on populations of forest-dwelling mice (*Apodemus flavicollis*) and carabid beetles. Small habitat islands tend to hold more animal species than expected according to the island biogeographic theory. The N_s/N_i ratio is highest in small isolates, indicating continuous movement of individual animals from surrounding agricultural areas resulting in unstable species composition.

Mader, H. J.; Schell, C.; Kornacker, P. 1990. Linear barriers to arthropod movements in the landscape. Biological Conservation. 54: 209-222.

Madsen, A. B. 1990. Otters (*Lutra lutra*) and traffic. Flora Og Fauna. 96: 39-46.
As an introduction, the number of otters killed by cars in Denmark and other European countries is presented showing that the problem is not insubstantial. The investigation is based on the following sources: information of 39 otters killed by cars and delivered to the Natural History Museum, Arhus, observations on crossing behaviour at 48 different bridges with possibilities for marking, experiences with game mirrors placed at 13 bridges across River Skals and direct observations of otters crossing the road at the dam of Virksund. Many otters were killed at places without banks under bridges or at dams between two wetlands. Although otters are killed in all months of the year, an increasing trend of collisions are seen in the months July to December. Twenty-five (64.1%) male otters, especially adult sexually mature males were killed in the traffic, probably as a result of their greater activity in the home-range than of females. In 66 (73.3%) of the visits at bridges with banks, the otters preferred to mark with spraints at the bank rather than outside the bridge. Footprints and tracks on banks showed that the otter in many cases continued under the bridge. The effect of game-mirrors at bridges to prevent traffic killing of otters is evaluated to be smaller than the efforts. Problems with maintenance is extensive in relation to a full non-risk possibility for passage. Direct observations seem to show that otters are not able to estimate the risk in passing roads. The consequence of the above-mentioned investigations is that we must try to avoid that otters cross the roadway, either by luring them under road systems on stones and banks or by forcing them away from the road by means of fences.

Madsen, A. B. 1996. Otter (*Lutra lutra*) mortality in relation to traffic, and experience with newly established fauna passages at existing road bridges. Lutra. 39(2): 76-88.
Like other wild animals, many European otters are killed by road traffic. This paper presents an evaluation of the following sources: data from 115 otters killed by cars during 1980 to 1995, examination of the scenes of accident and tests of ten fauna passages of various types constructed at existing road bridges. No significant difference was found in the number of traffic casualties between the winter months October-March and the summer months April-September. Adult, sexually mature males are most frequently killed by traffic, probably as a result of their greater activity as compared to females.

Nearly half of the otters were killed at bridges/culverts or dams. It is concluded that the most dangerous kinds of road for otters are highways/primary roads and secondary roads wider than 6 m with a relatively high traffic density and speed. Preventive measures must therefore start here. Many otters are killed at sites up to several kilometers from wetlands, probably taking 'shortcuts' between watersheds. Such 'shortcuts' may be a way in which genetic material can be exchanged between solitary animals such as otters. The provision of appropriately sited fauna passages is an effective means of reducing the number of traffic-killed otters. Two types of fauna passages are recommended for making existing road bridges safe and attractive for otters at a relatively small expense.

Madsen, Jesper. 1985. Impact of disturbance on field utilization of pink-footed geese in West Jutland, Denmark. Biological Conservation. 33(1): 53-63.

Maehr, D. S.; Land, E. D.; Roelke, M. E. 1991. Mortality patterns of panthers in southwest Florida. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies. 45: 201-207.

Maehr, D. S. 1992. Florida panther research: Florida panther recovery plan implementation. Florida panther distribution and conservation strategy. [Location of publication unknown]: Florida Game and Freshwater Fish Commission. 30 p.

Maine Cooperative Wildlife Research Unit. 1983. Wildlife populations utilizing right-of-way habitats along Interstate 95 in northern Maine - final report. Bangor, ME: Maine Department of Transportation, Materials and Research Division, Maine Cooperative Wildlife Research Unit; FHWA-ME-TP-83/5. 34 p.
From 1975 to 1982, the impact of constructing Interstate 95 in northern Maine on the distribution, abundance, and diversity of birds, rodents, and other mammals was assessed. Populations and activities of breeding birds and mammals were examined before, during, and after construction of I-95 along sections adjacent to various forest habitat types. Movements and densities of birds and mammals adjacent to and away from I-95 did not differ significantly during and after construction. The use and avoidance of newly created edges by some species was examined. Immediate losses of habitats for breeding birds were noted, and the long-term effects on populations of birds and mammals are discussed.

Mamalis, J. 1995. Wildlife use of the Trans-Canada Highway, phase III. Banff, Alberta: Parks Canada, Banff National Park Warden Service 13 p.
This study was initiated to evaluate effects of twinning/fencing on wildlife movement and to facilitate the placement of wildlife crossing structures along a section of the Trans Canada Highway (TCH). This study focused on examining winter wildlife use of the TCH phase III in relation to crossings over and under the highway. Objectives were 1) to determine areas of the highway that are preferred crossing points for various species and areas that are avoided; 2) to analyse general topographic/habitat features which may make areas attractive/unattractive crossing points; 3) to determine the effect of roadside snowdepth on wildlife crossings and relate this to topography and road characteristics; and 4) to further examine the use of culverts along phase III by small mammals, as related to culvert characteristics. Roadside snow tracking was used to document 'successful' and 'unsuccessful' crossing attempts. Distribution of animal crossing locations was not random. Factors that influenced corridor location included snowfall, highway fencing, and topography.

Mamalis, J. 1996. Wildlife use of highway underpasses phase I & II Trans-Canada Highway. Banff, Alberta: Parks Canada, Banff National Park Warden Service 28 p.

Mannaert, P. 1978. The mortality of small animals on roads. Lutra. 0(1-3): 23-24.

Mannaert, P. 1979. The mortality of small mammals along highways. Lutra. 1(1-3): 24-29.

Mansergh, I. M.; Scotts, D. J. 1989. Habitat continuity and social organization of the mountain pygmy-possum restored by tunnel. Journal of Wildlife Management. 53(3): 701-707.

They documented that the barrier effect of a road had altered movement patterns and social structure of mountain pygmy-possum. Over-winter survivorship (particularly for females) was low compared to populations in unfragmented habitat. When crossing tunnels were installed, they were used immediately and over-winter survivorship and social structure was similar to unfragmented areas.

Marcy, L. E. 1986. Environmental impact research program. Impassable wire fences: Section 5.2.3, U.S. Army Corps of Engineers Wildlife Resources Management Manual. Vicksburg, MS: Army Engineer Waterways Experiment Station, Environmental Lab; WES/TR/EL-86-7. 20 p.
A management techniques report on impassable wire fences is provided as Section 5.2.3 of the U.S. Army Corps of Engineers Wildlife Resources Management Manual. The report was prepared as a guide to assist Corps biologists and resource managers in the selection and implementation of impassable wire fence techniques where these fences are required or desirable for wildlife and habitat management programs. Topics covered include description, design and construction, placement, personnel and costs, maintenance, and cautions and limitations. Impassable wire fences are barriers that restrict wildlife access into areas that are hazardous or where grazing is not desired. They may be required along concrete-lined canals to prevent drowning or maiming of wildlife, and are often needed along highways to prevent large mammals from becoming a hazard to motorists. Impassable fences may also prevent destruction of newly planted habitats, nesting areas, and riparian vegetation. Two basic types of impassable fences, upright fences and slanting fences, are described in this report. Details are provided on their design, construction, installation, maintenance, and placement in suitable terrain. Specification drawings and lists of materials required for construction are included.

Marini, M. A.; Robinson, S. K.; Heske, E. J. 1995. Edge effects on nest predation in the Shawnee National Forest, southern Illinois. Biological Conservation. 74(3): 203-213.
Edge habitats may be considered 'ecological traps' for breeding birds if they attract many birds because of apparently favorable nesting conditions but have higher nest predation levels than interior habitats, Four alternative, nonexclusive hypotheses have been suggested to explain why edges might have higher predation levels than interior habitats: (1) predator activity is higher in areas with higher prey density (density-dependent predation), (2) predators are more abundant on edges than in forest interior, (3) the predator community is richer in species on edges than in forest interior; and (4) predators forage along travel lanes (linear geographical features) such as edges. Here we evaluated whether forest-farm edges in southern Illinois have ecological traps, and examined the relevance of these four hypotheses at our study sire with several different experiments during May to July 1992 using artificial nests (n = 605) bailed with quail eggs and placed on the ground, in shrubs, or in saplings. Our results showed that, in general, the forest-farm edges of southwestern Illinois did not attract significantly more individuals or species of nesting songbirds, but they did have higher nest predation levels than forest interior sites, primarily as a result of higher predation levels on sapling nests. We did not find evidence strongly supporting any of the four hypotheses suggested as explanations for higher nest predation levels near edges. Two data sets showed that predation levels on artificial nests were density-independent. Forest-farm edges had neither more total species of potential nest predators nor more individual predators. However, there were more species of avian predators on edges than in interior sites. Correlations between predator abundance and nest predation levels on individual transects were weak. The travel lane hypothesis was not supported because nest predation levels were either not affected by distance from linear geographical features (roads and ravines) or were significantly less when close to than when far from presumptive travel lanes. High spatial heterogeneity in predation levels, numbers of singing birds, and potential nest predators may have obscured general patterns and suggest a need for larger sample sizes. Edges may be detrimental to some species of singing birds but nor to others, and for different reasons.

Markham, D. 1996. The significance of secondary effects from roads and road transport on nature conservation. English Nature Reports. 78(March):1-A4.

Martinez-Abrain, Alej. 1994. Seasonal bird casualties on a road at the Albufera Lagoon Natural Park, E. Spain. Doana Acta Vertebr. 21(1): 90-95.

Marzluff, J. M. 1997. Effects of urbanization and recreation on songbirds. In: Block, W. M.; Finch, D. M., eds. In: Songbird ecology in southwestern ponderosa pine forests: a literature review. Gen. Tech. Rep. RM-GTR-292. Ft. Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 89-102.
This paper reviews the literature on the role of urbanization and recreation in changing ecosystem processes, habitat, food supply, predators, and disease for passerine birds. Roads may decrease songbird productivity because increased road-kills and litter may subsidize nest predators and provide them with foraging corridors into the forest interior. Road related habitats were suggested to favor scavengers and small seed eaters. Six bird species or groups of species were hypothesized to increase in abundance due to roads (crow, raven, house sparrow, juncos, red crossbill, other finches), while seven decreased (American robin, ground nesting warblers, shrub nesting warblers, canopy nesting warblers, tanangers, grosbeaks, and song sparrow).

Massemin, S.; Lemaho, Y.; Handrich, Y. 1998. Seasonal pattern in age, sex and body condition of barn owls (*Tyto alba*) killed on motorways. Ibis. 140(1): 70-75.
The barn owl (*Tyto alba*) was the most common owl killed on motorways in northeastern France. The possible causes of this mortality and the age, sex and body condition of the road-killed birds in 1991 to 1994 have been investigated. The number of birds killed on roads was highest in the period from early autumn to late winter, i.e., during the nonbreeding period, and showed a pattern similar to that of the temporal difference between sunset, which varies with day length, and peak of traffic, the occurrence of which is constant throughout the year. An autumnal mortality peak, concomitant with the postfledging dispersal, was mainly of immature birds, especially females. A second mortality peak in late winter was composed mainly of mature birds, with an equal proportion of males and females, From autumn to winter, there was no significant change in body mass in the different age and sex categories of birds killed on roads, except for mature males which had a significantly lower body mass in winter, From early autumn to late winter, the mean body mass of immature owls killed on motorways did not differ significantly from that of captive immatures fed *ad libitum*. This suggests that the immature birds were in good body condition, In contrast, the body mass of road-killed mature females was significantly lower than that of captive mature females over the same time periods. In mature males in late winter, a drop in body mass in both road-killed and captive birds suggests an endogenous seasonal phenomenon. Except for mature females, barn owls killed on roads in 1991 to 1994 were in good body condition, This does not support the idea that only birds in poor body condition were killed, We conclude that the mortality of barn owls on motorways in autumn and winter was probably related to the concomitance between the peak of traffic and the onset of hunting activity and the large number and dispersal of immature individuals during the same period.

Massemin, Sylvie; Le Maho, Yvon; Rich, Yves. 1996. Identification of the origins of barn owl (*Tyto alba*) killed or injured on motorways and their nutritional state. Alauda. 64(1): 56-57.

Massey, Adrianne. 1982. Ecology of house mouse populations confined by highways. Journal of the Elisha Mitchell Science Society. 98(3): 135-143.

Massey, C. I. 1971. A study of hedgehog road mortality in the Searborough District, 1966-1971. Leeds: Naturalist. 922(1):23.

Mattson, D. J.; Knight, R. R.; Blanchard, B. M. 1987. The effects of developments and primary roads on grizzly bear habitat use in Yellowstone National Park, Wyoming. International Conference on Bear Research and Management. 7: 259-273.
Aerial locations of radio-instrumented grizzly bears (*Ursus arctos*) were used to analyze effects of human activity associated with developments and primary roads on grizzly bear habitat use in Yellowstone National Park. Grizzly bear occupancy of habitat near human facilities was reduced, efficient foraging strategies were disrupted, and cohorts tending to be subordinate or security-conscious were displaced into habitat nearer developments by more dominant cohorts, particularly during summer and fall. Adult females and subadult males residing closer to developments were

management-trapped at a higher rate than animals of the same class residing farther away. Adult females and subadults bore a disproportionate part of costs associated with avoiding roads and developments. For this reason and because adult females are generally thought to operate under considerable energetic duress in the Yellowstone area, avoidance of developments and roads may have resulted in higher mortality and lower productivity among the adult female cohort.

Mattson, D. J.; Blanchard, B. M.; Knight, R. R. 1992. Yellowstone grizzly bear mortality, human habituation, and whitebark pine seed crops. Journal of Wildlife Management. 56: 432-442.
The Yellowstone grizzly bear (*Ursus arctos horribilis*) population may be extirpated during the next 100 to 200 years unless mortality rates stabilize and remain at acceptable low levels. Consequently, we analyzed relationships between Yellowstone grizzly bear mortality and frequency of human habituation among bears and size of the whitebark pine (*Pinus albicaulis*) seed crop. During years of large seed crops, bears used areas within 5 kilometers of roads and 8 kilometers of developments half as intensively as during years of small seed crops because whitebark pine's high elevation distribution is typically remote from human facilities. On average, management trappings of bears were 6.2 times higher, mortality of adult females 2.3 times higher, and mortality and subadult males 3.3 times higher during years of small seed crops. We hypothesize that high mortality of adult females and subadult males during small seed crop years was a consequence of their tendency to range closest (of all sex-age cohorts) to human facilities; they also had higher frequency of human habituation compared with adult males. We also hypothesize that low mortality among subadult females during small seed crop years was a result of fewer energetic stressors compared with adult females and greater familiarity with the range compared with subadult males; mortality was low even though they ranged close to humans and exhibited a high frequency of human habituation. Human- habituated and food-conditioned bears were 2.9 times as likely to range within 4 kilometers of developments and 3.1 times as often killed by humans compared with nonhabituated bears. We argue that destruction of habituated bears that use native foods near humans results in a decline in the overall ability of bears to use available habitat; and that the number and extent of human facilities in occupied grizzly bear habitat needs to be minimized unless habituated bears are preserved and preserved and successful ways to manage the associated risks to humans are developed.

May, S. A.; Norton, T. W. 1996. Influence of fragmentation and disturbance on the potential impact of feral predators on native fauna in Australian forest ecosystems. Wildlife Research. 23(4): 387-400.
We review current knowledge of the diet and predator-prey relationships of the feral cat (*Felis catus*), fox (V*ulpes vulpes*) and dingo (*Canis familiaris dingo*) (including wild dogs), and consider how forest fragmentation by roads may influence the use of native forest ecosystems by these species and the significance of this for native fauna. The cat, fox and dingo are significant predators in Australia that interact with native fauna in various ways, including predation, competition for resources, and transmission of disease. Generally, dingoes prey upon large to medium-sized prey species (e.g., wallabies, common wombats, and possums), foxes prey upon medium-sized to small prey (e.g., possums and rats) and consume a significant component of scavenged material and vegetation, while cats also prey upon medium-sized to small prey, but may have a greater proportion of reptiles and birds in their diet. Although many of Australia's forested areas are relatively heavily fragmented by roads, there are no published studies specifically investigating the use of roads by feral predators. The extent to which feral predators forage away from roads needs further investigation, as does the rates of predation within edges, because this may have several consequences for the design, location and size of retained strips and wildlife corridors as well as restoration programmes. Further observations on regional differences influencing predator-prey interactions are required, as is research on the potential impacts on native fauna resulting from prey selection in forests subjected to various degrees of fragmentation and modification.

Mayol, J. 1992. Mortality of *Tarentola mauritanica* on the rural roads of Menorca. Preliminary note. In: Lopez, Redondo, ed. I jornadas para el estudio y prevencion de la mortalidad de vertebrados en carreteras, Madrid, 5 y 6 de Octubre de 1991. Tomo 2. [Sessions in the study of prevention of road mortalities of vertebrates, Madrid, 5 and 6 October, 1991. Volume 2.]. Ambiental, Madrid: Coordinadora de Organizacciones de Defensa: 280-281.

McCaffery, K. R. 1973. Road kills show trends in Wisconsin deer populations. Journal of Wildlife Management. 37: 212-216.
Analysis by regression techniques showed numbers of road-killed white-tailed deer provide a useful index to deer population changes in Wisconsin. Road-kill trends correlated extremely well with trends in registered buck harvests. Only two ingredients are needed for a road-kill index: accurately reported road-kills, and an estimate of percent change in annual traffic volume.

McClure, H. E. 1951. An analysis of animal victims on Nebraska's highway. Journal of Wildlife Management. 15: 410-420.

McCool, Stephen F. 1978. Snowmobiles, animals, and man: interactions and management issues. Transactions of the North American Wildlife Natural Resource Conference. 43: 140-148.

McCrain, Gerald R. 1991. Highways and pocosins in North Carolina: an overview. Environmental Services, Inc. 11(Special issue): 481-488.

McDonald, M. G. 1988. Glenn Highway moose monitoring study progress report. Anchorage, AL: Alaska Department of Fish and Game; Second annual progress report. 25 p.
Fencing and an underpass were installed along a moose migration corridor.

McDonald, M. G. 1991. Moose movement and mortality associated with the Glenn Highway expansion, Anchorage, Alaska. Alces. 27: 208-219.
They compare moose movement and mortality before and after a highway was expanded from four to six lanes. Mitigation included fencing, an underpass, one-way gates, and lighting. Moose mortality declined by 70% overall and by 95% in the fenced area after installation of the mitigation measures. They documented moose movement patterns using radio-telemetry.

McDougal, L. A.; Vaughan, M. R.; Bromley. 1990. Wild turkey and road relationships on a Virginia National Forest. Blacksburg, VA: Virginia Department of Fish and Wildlife Science; 6. 106 p.

McLaren, Margaret A.; Jeffrey, E. G. 1985. The reactions of muskoxen to snowmobile harassment. Arctic. 38(3): 188-193.

McLellan, B.; Shackleton, D. M. 1989. Immediate reactions of grizzly bears to human activities. Wildlife Society Bulletin. 17: 269-274.

McLellan, B. N.; Shackleton, D. M. 1988. Grizzly bears and resource-extraction industries: effects of roads on behavior, habitat use and demography. Journal of Applied Ecology. 25: 451-460.
Roads are an integral part of the development of resource-extraction industries. We wanted to know whether grizzly bears were displaced by these roads from adjacent habitats. Over 7 years, 27 grizzly bears were captured and radio-collared in 264 square kilometers of the Rocky Mountains, containing active tree-felling and petrocarbon developments. Most bears used habitats within 100 meters of roads less than expected. This is equivalent to a loss of 8.7%. This is significant because many habitats close to roads contain important bear foods. Avoidance of roads was independent of traffic volume, suggesting that even a few vehicles can displace bears. Roads and nearby areas were used at night but avoided in the day. Yearlings and females with cubs used habitats near roads more than other bears. These areas may have been relatively secure because they were avoided by potentially aggressive adult males. Limited data indicated minimal demographic effects during our study, but roads increased access for legal and illegal hunters, the major source of adult grizzly mortality. When roads are developed for

resource industries in grizzly bear habitat, the bear population becomes highly vulnerable unless vehicle access and people with firearms are controlled.

McLellan, B. N. 1989. Effects of resource extraction industries on behavious and population dynamics of grizzly bears in the Flathead drainage, British Columbia and Montana. Vancouver, BC: University of British Columbia. [Pages unknown]. Ph.D. dissertation.

McLellan, B. N.; Shackleton, D. M. 1989. Grizzly bears and resource-extraction industries: habitat displacement in response to seismic exploration, timber harvesting and road maintenance. Journal of Applied Ecology. 26: 371-380.
The response of grizzly bears (*Ursus arctos*) to gas exploration and timber harvest was investigated by comparing the locations of radio-collared individuals before, during, and after the activity in five tests. In the first test, there was no significant difference in distribution of four bears involved in eleven bear-seismic situations over 3 years (data combined). In comparisons of within-year distributions of individual bears, two of the 11 bears showed a significant difference in habitat use. Significant displacement was not found in the four other bear-industry interactions, including two seismic, one road maintenance and one timber harvest activity. These activities all occurred in spring, when bears are more mobile than in summer. The effect of industrial activity on the productivity of the test bears, the potential factors influencing the general lack of displacement, and management implications are discussed.

McRae, Michael. 1997. Road kill in Cameroon. Natural History. 106(1): 36-75.
The author discusses the demise of wild animal populations in Cameroon. Roads constructed in conjunction with the logging industry provide access into wildlife habitat and the vehicles provide a means of transportation of animal carcasses to market.

Mead, Chris. 1993. Use by birds of roads for navigation. British Birds. 86(8): 375-376.

Means, B. 1996. A preliminary consideration of highway impacts on herpetofauna inhabiting small isolated wetlands in the southeastern U.S. coastal plain. In: Evink, G.; Ziegler, D.; Garrett, P.; Berry, J., eds. Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors: Proceedings of the Florida Department of Transportation/Federal Highway Administration transportation-related wildlife mortality seminar; 1996 April 30-May 2; Orlando, FL. FHWA-PD-96-041. Washington, DC: U.S. Department of Transportation, Federal Highway Administration: 297-307.
This report recommends monitoring and research prior to highway reconstruction.

Mech, L. D.; Fritts, S. H.; Radde, G. L.; Paul, W. J. 1988. Wolf distribution and road density in Minnesota. Wildlife Society Bulletin. 16: 85-87.
Wolf distribution is correlated with low road density.

Mech, L. D. 1989. Wolf population survival in an area of high road density. American Midland Naturalist. 121: 387-389.
Wolf mortality in a high-road-density area of Minnesota exceeds that in an adjacent wilderness, and is primarily human-caused. The wolf population there is maintained primarily by ingress from the adjacent wilderness areas. A road density of 0.58 km/km^2 can be exceeded and the area still support wolves if it is adjacent to extensive roadless areas.

Meinig, H. 1989. Experience and problems with a toad tunnel system in the Mittelgebirge region of West Germany. In: Langton, T. E. S., ed. Amphibians and roads. Proceedings of the toad tunnel conference; 1989 January 7-8; Rendsburg, Federal Republic of Germany. Shefford, England: ACO Polymer Products Ltd.: 59-66.

Meitz, S. N. 1994. Linkage zone identification and evaluation of management options for grizzly bears in the Evaro Hill area. Bozeman: University of Montana. 91 p. M.S. thesis.

Mendelson, J. R., III; Jennings, W. B. 1992. Shifts in the relative abundance of snakes in a desert grassland. Journal of Herpetology. 26(1): 38-45.
Distribution, diversity and relative abundance of snake species on roads through desert grasslands in Arizona and New Mexico (USA) were compared to data in a previously published survey conducted about 30 years ago. We found a significant shift in the relative abundance of snake species: *Thamnophis marcianus* and *Crotalus atrox* have increased in relative abundance and *C. scutulatus* has decreased. These changes are correlated with succession of local semidesert grasslands to Chihuahuan Desert scrub. Analysis of distributions of *Crotalus* revealed that *C. atrox* was more common than *C. scutulatus* in scrub habitat while *C. scutulatus* was more common in the remaining grasslands.

Merriam, G.; Kozakiewicz, M.; Tsuchiya, E.; Hawley, K. 1989. Barriers as boundaries for metapopulations and demes of *Peromyscus leucopus* in farm landscapes. Landscape Ecology. 2(4): 227-235.
Effects of potential barriers (roads and cultivated fields) on both demographic and genetic features of subpopulations of white-footed mice were studied near Ottawa, Canada. Live trapping, colored bait and track registry were used to study animal movements across roads on four 1.44 hectare areas each within a small forest bisected by a narrow gravel road. The genetic study was done in 11 other forest fragments separated from each other by cultivated fields. Frequencies of three electrophoretic variants of salivary amylases were established for mice caught in each patch of wood and genetic similarity of subpopulations was calculated. Movements of mice across the roads were very infrequent (quantitative barrier), although movements adjacent to roads were frequent and long enough to cross the roads. Salivary amylase data showed that studied subpopulations were genetically very similar although the sample was intentionally biased toward demographic isolation. Results are discussed in terms of possible hierarchical relationships of metapopulations and genetic demes in the context of landscape ecology, management and conservation practice.

Merriam, G. 1991. Are corridors necessary for the movement of biota? In: Saunders, D. A.; Hobbs, R. J., eds. Nature conservation 2: the role of corridors. Chipping Norton, Australia: Surrey Beatty and Sons: 406-407.

Merriam, G. 1991. Corridors and connectivity: animal populations in heterogeneous environments. In: Saunders, D. A.; Hobbs, R. J., eds. Nature conservation 2: the role of corridors. Chipping Norton, Australia: Surrey Beatty and Sons: 133-142.

Messner, H. E.; Dietz, D. R.; Garrett, E. C. 1998. A modification of the slanting deer fence. Journal of Range Management. 26: 233-235.

Michael, E. D. 1975. Effects of highways on wildlife. Charleston, WV: West Virginia Department of Highways; WVDOH 42. [Pages unknown].
Field studies were conducted in Coopers Rock State Forest, northern West Virginia, to measure the impact of Appalachian Highway 48 on wildlife populations. Field data were collected from 1971 (the year prior to highway construction being initiated) to 1975 (one year after the highway was open to traffic). Changes in population densities were monitored by recording direct sightings and sign. The construction of the highway resulted in the creation of two new habitats which were not previously present, the right-of-way vegetation and ecotone. Responses of small mammals and song birds to these new habitats are discussed. Populations of some animals increase following highway construction while others decrease. Responses of major game animals. No game animal seemed to exhibit a change in distribution as a result of the highway being constructed. Also, no change in population density could be attributed to the presence of the highway.

Michael, E. D.; Ferris, C. R.; Haverlack, E. G. 1976. Effects of highway rights-of-way on bird populations. In: Tillman, R., ed. Proceedings of the first national symposium on environmental concerns in rights-of-way management. Starkville: Mississippi State University: 253-262.

Michael, E. D. 1978. Management of highway rights-of-way for wildlife. Congr. Theriol. Int. 2: 51-54.

Michael, E. D. 1980. Use of different roadside cover plantings by wildlife. Morgantown, WV: West Virginia University, Division of Forestry; WVDOH/56; FHWA/WV80/004. 100 p. Sponsored by West Virginia Department of Highways and Federal Highway Administration.
Use of three highway right-of-way (ROW) cover crops: crownvetch, (*Coronilla varia*) sericea lespedeza, (*Lespedeza cuneata*) and K-31 fescue, (*Festuca* sp.) were evaluated to determine use by various groups of wildlife. Data were collected on three groups of wildlife; small mammals, songbirds, and game animals. Mowed and unmowed sericea and fescue were examined to determine how mowing of ROW vegetation affects songbird use. Data were collected from October 1977 through July 1979 along I-79 and U.S. 48, in north-central West Virginia.

Michael, E. D. 1981. Management of highways for wildlife in the central Appalachians. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies. 34: 442-448.

Michael, Edwin D. 1978. Effects of highway construction on game animals. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies. 32: 48-52.

Michael, Edwin D.; Taylor, Curtis. 1978. Use of interstate highway cuts as starling nesting sites. Condor. 80(1): 113-115.

Michael, Edwin D. 1979. Visibility of birds along interstate highways. Redstart. 46(2): 82-87.

Mierau, G. W.; Favara, B. E. 1975. Lead poisoning in roadside populations of deer mice. Environmental Pollution. 8: 55-64.
Cited in Forman 1995, p.168, roads as source of toxins.

Mietz, S. N. 1994. Linkage zone identification and evaluation of management options for grizzly bears in the Evaro Hill area. Bozeman: University of Montana. 91 p. M.S. thesis.
The Evaro Hill area, northwest of Missoula, Montana, is the primary linkage zone between two major grizzly bear recovery areas. To aid in linkage area identification, Servheen and Sandstrom (1993) developed a GIS model which "scores" a landscape based on grizzly bear habitat value. The results of the model indicate that a single linkage zone remains in the Evaro Hill area.

Miller, B. K.; Litvaitis, J. A. 1992. Habitat segregation by moose in a boreal forest ecotone. Acta Theriologica. 37: 41-50.
We examined seasonal home range size and habitat use by sexes of moose *Alces alces* (Linnaeus, 1758) near the southern edge of this species' geographic range. Home range size did not differ between males and females during any season. The distribution of forage partly explained seasonal habitat use by both sexes. However, sites occupied by males in summer (1 June to 15 September) and autumn (16 September to 31 December) were at higher elevations, had steeper slopes, and were farther from potential aquatic feeding sites than sites used by females. We suggest that habitat segregation during these seasons was a consequence of differential resource requirements, not active avoidance by either sex. During summer, females occupied lowland sites near forest cuts, presumably because these sites had abundant forage and dense understory cover that concealed their young from predators. Additionally, females utilized roadside salt licks more often than males during summer and autumn. Males occupied upland hardwood stands during summer in an apparent effort to avoid heat stress and maximize forage intake. Habitat characteristics of both sexes were similar during winter when resource needs were probably equivalent, and the quality and distribution of forage were more homogenous.

Miller, B. K.; Litvaitis, J. A. 1992. Use of roadside salt licks by moose, *Alces alces*, in northern New Hampshire. Canadian Field Naturalist. 106: 112-117.
We investigated use of roadside salt licks by 14 transmitter- equipped Moose (*Alces alces*) during June to November 1987 and June to August 1988. Roadside licks formed from runoff of road salt and contained much higher levels of sodium (hivin x 628.5 ppm) than roadside puddles (hivin x 45.9 ppm), or stream water (hivin x = 5.2 ppm). Females visited licks more often (8% of telemetry locations) than males (2% of locations) (P = 0.049). Frequency of use varied from 6% of telemetry locations during summer (June to August) to 12% of locations during autumn (September to November) for females, and from 1 to 3% among males for the same season. The average distance between seasonal centers of activity and roadside licks was approximately 60% greater among males (10.1 km) than among females (6.4 km) (P = 0.011). There was no correlation between that distance and the size of seasonal home ranges. However, home ranges of 11 Moose (three males and eight females) were elongated and incorporated at least one lick. All home ranges converged on the area containing the roadside licks. Implications associated with roadside licks include increased moose-vehicle collisions, and potential increased brainworm (*Parelaphostrongylus tenius*) infections among moose from white-tailed Deer (*Odocoileus virginianus*) that also used licks.

Miller, F. L.; Jonkel, C. J.; Garrett, E. C. 1972. Group cohesion and leadership response by barren-ground caribou to man-made barriers. Arctic. 25: 193-201.
Fencing should be totally restrictive and be constructed in the general direction of animal movements.

Miller, F. L. 1983. Some physical characteristics of caribou spring migration crossing sites on the Dempster Highway, Yukon Territory. Proceedings of the Alaska Science Conference. 34: 15-20.

Miller, J. R.; Joyce, L. A.; Knight, R. L.; King, R. M. 1996. Forest roads and landscape structure in the southern Rocky Mountains. Landscape Ecology. 11(2): 115-127.
Roadless areas on public lands may serve as environmental baselines against which human-caused impacts on landscape structure can be measured. We examined landscape structure across a gradient of road densities, from no roads to heavily roaded, and across several spatial scales. Our study area was comprised of 46,000 hectares on the Roosevelt National Forest in northcentral Colorado. When forest stands were delineated on the basis of seral stage and cover type, no relationship was evident between average stand size and road density. Topography appeared to exert a greater influence on average stand size than did road density. There was a significant cant positive con-elation between the fractal dimension of forest stands and road density across all scales. Early-seral stands existed in greater proportions adjacent to roads, suggesting that the effects of roads on landscape structure are somewhat localized. We also looked at changes in landscape structure when stand boundaries were delineated by roads in addition to cover type and seral stage: Overall, there was a large increase in small stands with simple shapes, concurrent with a decline in the number of stands > 100 hectares. We conclude that attempts to quantify the departure from naturalness in roaded areas requires an understanding of the factors controlling the structure of unroaded landscapes, particularly where the influence of topography is great. Because roads in forested landscapes influence a variety of biotic and abiotic processes, we suggest that roads should be considered as an inherent component of landscape structure. Furthermore, plans involving both the routing of new roads and the closure of existing ones should be designed so as to optimize the structure of landscape mosaics, given a set of conservation goals.

Miller, T. O. 1975. Big game investigations: factors influencing black bear habitat selection on Cheat Mountain, West Virginia. Charleston: West Virginia Department of Natural Resources 67 p.

Millsap, Brian A.; Maurice, N. L. 1988. Road transect counts for raptors: how reliable are they? Journal of Raptor Research. 22(1): 8-16.

Ministry of the Environment. 1995. Wildlife accident reporting system (WARS) annual report. Vancouver, B.C.: Highway Environment Branch.

Mitchell, J.; Mayer, R. 1997. Diggings by feral pigs within the wet tropics world heritage area of North Queensland. Wildlife Research. 24(5): 591-601.
The association of ground-digging activity of feral pigs with a range of environmental variables was examined in the wet tropics World Heritage Area of north Queensland. Approximately 4% of the surveyed ground was disturbed by digging activity of feral pigs. Significant differences in diggings were detected between highland and lowland areas and between habitat types. Diggings were more prevalent in lowland areas and coastal swamp habitats. Diggings were positively associated with roads, tracks and moist drainage lines.

Mitchell, S. 1994. Effects of a four-wheel drive road on riparian communities in Canyonlands National Park, Utah. Journal of the Colorado-Wyoming Academy of Science. 26(1): 36-41.

Mladenoff, D. J.; Sickley, T. A.; Haight, R. G.; Wydeven, A. P. 1995. A regional landscape analysis and prediction of favorable gray wolf habitat in the northern Great Lakes Region. Conservation Biology. 9(2): 279-294.
Over the past 15 years the endangered eastern timber wolf has been slowly recolonizing northern Wisconsin and, more recently, upper Michigan, largely by dispersing from Minnesota (where it is listed as threatened). We have used GIS and spatial radio-collar data on recolonizing wolves in northern Wisconsin to assess the importance of landscape-scale factors in defining favorable wolf habitat. We built a multiple logistic regression model applied to the northern great states to estimate the amount and spatial distribution of favorable wolf habitat at the regional landscape scale. Variables that were significant in comparing new pack areas in Wisconsin to nonpack areas included land ownership, land cover type, road density, human population, land cover type contagion, landscape diversity, and landscape dominance. Road density and fractal dimension were the most important predictor variables in the logistic regression models.

Mocci, Demartis. 1985. Mortality of birds on the roads and their density. Proceedings of the International Ornithology Congress. 18: 1147-1149.

Modafferi, R. D. 1991. Train moose-kill in Alaska: characteristics and relationship with snowpack depth and moose distribution in Lower Susitna Valley. Alces. 27: 193-207.

Moen, Aaron N.; Whittemore, Susan; Buxton, Bonnie. 1982. Effects of disturbance by snowmobiles on heart rate of captive white-tailed deer. New York Fish and Game Journal. 29(2): 176-183.

Mooij, Johan H. 1982. The effects of highways upon the avifauna on an open landscape of the Lower Rhine (North Rhine-Westphalia), inquiry into the behavior of wild geese. Charadrius. 18(3/4): 73-92.

Moore, T. G.; Mangel, M. 1996. Traffic related mortality and the effects on local populations of barn owls (*Tyto alba*). In: Evink, G.; Ziegler, D.; Garrett, P.; Berry, J., eds. Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors: Proceedings of the Florida Department of Transportation/Federal Highway Administration transportation-related wildlife mortality seminar; 1996 April 30-May 2; Orlando, FL. FHWA-PD-96-041. Washington, DC: U.S. Department of Transportation, Federal Highway Administration: 125-140.
The authors investigated roadkill mortality of barn owls along 236 kilometers of four lane divided highway from May 25, 1995 to November 26, 1995. They found 227 owls; 61% were juveniles, 74% were female. Other species collected included red-tailed hawk (12), mallard (12), and pheasant (17).

Morant, P. D.; Winter, C. 1983. Carrion feeding by kelp gulls (*Larus dominicanus*) in Patagonia, Argentina. Cormorant. 1(1-2): 65-67.

Morris, P. A.; Morris, M. J. 1989. Distribution and abundance of hedgehogs (*Erinaceus europaeus*) on New Zealand roads. New Zealand Journal of Zoology. 5(4): 491-498.

Morris, R. L.; Tanner, W. W. 1969. The ecology of the western spotted frog (*Rana Pretiosa Pretiosa* baird and girard), a life history study. Great Basin Naturalist. XXIX: 45-81.

Morrison, Michael L.; Mills, L. S. ; Kuenzi, Amy J. 1996. Study and management of an isolated, rare population: the Fresno kangaroo rat. Wildlife Society Bulletin. 24(4): 602-606.
A study of the Fresno kangaroo rat on the naval air station at Lemoore, California is described. The effect of road building and human use of its habitat are discussed.

Moser, J. K.; Pojar, T. M.; Woodard, T. N. and others. 1972. Deer underpass evaluation. Denver, CO: State of Colorado, Division of Wildlife.; Project No. W-38-R-26, Work Plan No. 15, Job 6. [Pages unknown].
The use of a concrete box deer underpass 10 x 10 feet and 100 feet long that permits deer to move under I-70 to and from their summer range has been evaluated. The structure is located 4.3 miles west of Vail and utilizes a well established deer migration trail and a natural drainage. According to the number of passages recorded by an electro-optical detection system, an increase of 31% occurred from 1970 to 1971. The greatest use of the underpass occurred during the June and the October-November periods with maximums of 16 and 28 deer per day, respectively. Detectors were placed at both the entrance and exit of the underpass. An index of entrance versus exit activity has indicated a behavioral reluctance on the part of the animals to use the underpass.

Munguira, M. L.; Thomas, J. A. 1992. Use of road verges by butterfly and burnet populations and the effect of roads on adult dispersal and mortality. Journal of Applied Ecology. 9(2): 316-329.
Transects made beside 12 main roads in Dorset and Hampshire (UK) showed that verges and central reservations supported a wide variety of butterflies and burnets (*Zygaenidae*). One site had 23 species of butterfly (=40% of British species), while the average was nine (16%) species per 100-meter transect. Most were common species, but some rarities were present. Mark-recapture estimates of adult densities on verges were up to 2,774 adults ha-1 for *Maniola jurtina*. Populations of *Melanargia galathea*, *Pieris rapae* and *Polyommatus icarus* were large or medium-sized for these species. Variation in the number of species, density and diversity of butterflies and burnets depended on the range of breeding habitat on verges. The density of adults and number of species were correlated with verge width, while diversity was correlated with the abundance of nectar. The amount of traffic had no apparent effect on populations on verges. Road verges could be substantially improved for butterflies and burnets by reducing the depth of top soil and amount of fertilizer applied, by planting with native seed mixes and shrubs, by creating an irregular topography and surrounding them with hedges, and by making verges and central reservations as wide as possible. Wide busy roads were no barrier to the movements of species living in open populations, but slightly impeded those with closed populations. Mark-recapture showed that 10-30% of adults of three species with closed populations crossed the road. Roads cannot be considered as a barrier to gene flow in any species in this study. Vehicles killed 0.6-1.9% of adults of species from closed populations, and about 7% of those from open populations. These mortalities were insignificant compared to those caused by natural factors.

Murphy, S. M.; Curatolo, J. A. 1986. Activity budgets and movements of caribou encountering pipelines, roads and traffic in northern Alaska. Canadian Journal of Zoology. 65: 2483-2490.
Insect harassment significantly affected caribou behavior by decreasing time spent feeding and lying and by increasing locomotion. Effects of oilfield disturbance on behavior were most pronounced when insects were absent, suggesting that disturbance and insects did not have a substantial additive effect on behavior. When insects were absent, caribou within 600 meters of an elevated pipeline and road with traffic, and within 300 meters of a pipeline and road without traffic, had significantly different activity budgets than undisturbed caribou; disturbance effects were significantly greater in the site with traffic. Time spent lying and running and movement rates were the best indicators of oilfield disturbance, whereas time spent feeding was not affected. Cow/calf dominated groups and groups larger than 10 animals reacted to lower levels of disturbance than other group types, but all group types reacted similarly to high levels of disturbance. Separation of elevated pipelines from heavily traveled roads is recommended as a means of minimizing disruption of caribou behavior and movements.

Energetic stress resulting from disturbance-induced changes in behavior should be minimal in a properly designed oilfield.

Muskett, C. J.; Jones, M. P. 1980. The dispersal of lead, cadmium and nickel from motor vehicles and effects on roadside invertebrate macrofauna. Environmental Pollution (Series A). 23: 231-242.

Muzzi, D.; Bisset, A. 1990. Effectiveness of ultrasonic wildlife warning devices to reduce moose fatalities along railway corridors. Alces. 26: 37-43.
Railway accidents resulting in the fatality of big game may have a substantial impact on populations in the vicinity of the railroad right-of-way. Little research has been done on possible mitigation techniques. We evaluated the effectiveness of a commercially available wildlife warning device (Hobi Ultrasonic Whistle) when mounted on Canadian National Railway locomotives which cross the northwestern section of Ontario where moose are the principle big game species. Trains with whistles hit and killed significantly fewer moose than those not utilizing the devices ($P<0.05$). Also, the crews of locomotives with the devices attached took significantly fewer preventative actions to scare wildlife away from the tracks. Although the voluntary nature of participation by engineers operating the trains limited data quality, results suggest that the mounting of these ultrasonic whistles on locomotives could lead to a significant reduction in wildlife-train encounters and thus result in fewer moose fatalities.

Nankinov, D. N.; Todorov, N. M. 1983. Bird casualties on highways. The Soviet Journal of Ecology. 14: 288-293.
Bird casualties on Bulgarian highways are discussed. The number of bird casualties depends on the speed of the vehicle and the attractiveness of roadside biotopes. A total of 594 birds of 17 species were collected over 321 days. The highest number of birds died in August, June, and July. It is estimated that over 7 million birds are killed in Bulgaria each year.

Neff, D. J. 1972. Statewide investigations: effects of motor vehicle closure on game populations. Flagstaff, AZ: Arizona Game and Fish Department; Project No.1973. 12 p.

Neil, P. H.; Hoffman, R. W.; Gill, R. B. 1975. Effects of harassment on wild animals--an annotated bibliography of selected references. Denver, CO: State of Colorado, Division of Wildlife; Special Report 37. 21 p.

Nellemann, Christian; Cameron, Raymond D. 1996. Effects of petroleum development on terrain preferences of calving caribou. Arctic. 49(1): 23-28.
Rangifer tarandus in Alaska.

Nelson, G. C.; Hellerstein, D. 1997. Do roads cause deforestation - using satellite images in econometric analysis of land use. American Journal of Agricultural Economics. 79(1): 80-88.
In this paper we demonstrate how satellite images and other geographic data can be used to predict land use. A cross-section model of land use is estimated with data for a region in central Mexico. Parameters from the model are used to examine the effects of reduced human activity. If variables that proxy human influence are changed to reflect reduced impact, "forest" area increases and "irrigated crop" area is reduced.

Nero, R. W. 1981. High mortality of great gray owls in Manitoba - winter 1980-81. Blue Jay. 39: 158-165.

Nero, R. W. 1986. Great grey owls apparently feeding on frogs on roads at night. Blue Jay. 4(3): 189-190.

Neumann, Peter W.; Merriam, H. G. 1972. Ecological effects of snowmobiles. Canadian Field Naturalist. 86(3): 207-212.

Newbey, B. J.; Newbey, K. R. 1987. Bird dynamics of foster road reserve, near Ongerup, western Australia. In: Saunders, D. A.; Arnold, G. W.; Burbidge, A. A.; Hopkins, A. J., eds. Nature conservation: the role of remnants of native vegetation. Chipping Norton, Australia: Surrey Beatty and Sons: 341-345.

Newmark, W. D.; Boshe, J. I.; Sariko, H. I.; Makumbule, G. K. 1996. Effects of a highway on large mammals in Mikumi National Park, Tanzania. African Journal of Ecology. 34(1): 15-31.
Few quantitative studies have been conducted in Africa, either inside or outside of protected areas, on the impact of roads on large mammal populations. Foot surveys were conducted during the last two weeks of October, which is the late dry season, in 1988, 1989, 1991, and 1992 in the Mkata flood plain of Mikumi National Park in order to assess the distribution of 13 species of large mammal in relationship to a major trans-national highway that bisects the park. In grassland <1 meter in height, eland, bohor reedbuck, black-backed jackal, elephant, and wildebeest use areas significantly less than expected within 600 meters of the highway while zebra in the same vegetation type use areas significantly less than expected within 200 meters of the highway. In woodlands, wildebeest use areas less than expected within 600 meters of the highway. Patterns of highway mortality for large mammals within the park over a 16 year period were also examined. Between 1973 and 1988, park personnel recorded 456 highway mortalities of large mammals. The number of highway mortalities for both herbivores and carnivores is significantly and inversely correlated with monthly precipitation during this period indicating that most large herbivore and carnivore mortalities occur during the dry season. In addition, for carnivore species, the rank of the proportion of a species' diet that is scavenged or carrion is significantly correlated with the number of recorded highway mortalities. Large mammal species that are displaced by the highway in at least one vegetation cover type suffer highway mortalities proportionately less than or equal to their relative abundance; in contrast, large mammal species that are not displaced by the highway in any vegetation cover type suffer highway mortalities greater than their relative abundance.

Newton, I.; Willie, I.; Asher, A. 1991. Mortality causes in British barn owls (*Tyto alba*) with a discussion of aldrin-dieldrin poisoning. Ibis. 133: 162-169.
The main causes of recorded deaths were collisions (mostly with road traffic) and starvation. No great seasonal variation occurred in the main causes of recorded deaths and starved juveniles were reported even in summer. Another important cause of mortality, at least to 1977, was poisoning by organochlorine pesticides. The carcasses received probably did not represent a random cross-section of barn owl deaths but were biased towards those forms of mortality most readily detected by people.

Nicholson, L. 1978. The effects of roads on desert tortoise populations. Desert Tortoise Council Proceedings. 1978: 127-129.

Nicholson, Peter. 1969. Counts of animal corpses on east Suffolk roads between September, 1966-September, 1968. Suffolk Natural History. 15: 67-69.

Nielsen, C. K.; Nelson, S. J.; Porter, W. F. 1997. Emigration of deer from a partial enclosure. Wildlife Society Bulletin. 25(2): 282-290.
Private landowners are increasingly interested in managing deer on small parcels of land. Deer-proof fences have been used to facilitate management on small landholdings, but where public roads and streams cross, fences must have openings. These openings create questions regarding deer management. In western New York State, a 3-meter-high fence with five openings was erected around a 319-hectare area with the intent of enhancing management of white-tailed deer (*Odocoileus virginianus*). We investigated the impacts of the fence and management within enclosures on movements of deer, assessing their contributions to quality deer management (QDM) goals. We radio-marked 67 deer during winters of 1992 to 1995 and calculated emigration rates. Emigration of yearlings was substantially less than from unfenced populations (23%), but through 30 months of age, 64% had emigrated. Emigration of females was more limited (10% through 30 months of age). Some deer moved in and out of the partial enclosure, and males suffered high mortality during hunting season as a consequence of this movement. Deer density estimates were 86 deer/km^2. Although harvest

regulations resulted in a decrease in the female proportion of the population over the study period (P = 0.004), there was no reduction in population density (0.522 < P < 0.968). Harvest of males >3 years of age increased from zero to six from 1992 to 1994. The partial enclosure appeared to delay emigration in most males and to retain a limited number of males on the property, thereby facilitating QDM.

Norling, B. S.; Anderson, S. H.; Hubert, W. A. 1992. Roost sites used by sandhill crane staging along the Platte River, Nebraska. Great Basin Naturalist. 52(3): 253-261.
We assessed the influence of water depth, extent of unobstructed view, and human disturbance features on use of roost sites by Sandhill Cranes along the Platte River, Nebraska, during spring migratory stopover. Aerial photos taken near dawn were used to determine areas of flock use and habitat availability in four sample reaches, and measurements were made on the ground at flock roost areas. In general, depths of 1 to 13 centimeters were used by sandhill cranes in greater proportion than those available. Exposed sandbars and depths >20 centimeters were avoided, while depths of 14 to 19 centimeters were used in proportion to their availability. Sites 11 to 50 meters from the nearest visual obstruction were used significantly greater than their availability, while sites 0 to 4 and >50 meters from visual obstructions were avoided. Sandhill Cranes avoided sites near paved roads, gravel roads, single dwellings, and bridges when selecting roost sites; however, they did not appear to be disturbed by private roads, groups of residential buildings, gravel pits, railroads, or electrical transmission lines.

Norman, T.; Finegan, A.; Lean, B. 1998. The role of fauna underpasses in New South Wales. In: Evink, G. L.; Garrett, P.; Zeigler, D.; Berry, J., eds. Proceedings of the international conference on wildlife ecology and transportation; 1998 February 10-12; Ft. Myers, FL. Tallahassee, FL: Florida Department of Transportation: 195-208.
Underpasses have been constructed on many highways in New South Wales, Australia, usually where new roads have been constructed through suspected or known fauna habitat or movement corridors. Despite the clear potential benefits of underpasses in facilitating fauna movement, evidence of their effectiveness is limited, equivocal, and usually relates to overseas situations. Some of the key concerns raised about the usefulness of underpasses relate to the cost of their installation, levels of predation by introduced carnivores, and the extent to which it is expected to utilize artificial habitat for movement. The Australian Museum (through AMBS Consulting (AMBS)) and the NSW Roads and Traffic Authority (RTA), worked together to identify some typical underpass situations on the F3, a major freeway north of Sydney, and monitored their usage by native and introduced animals over a period of 9 months. Three underpasses were monitored which varied in respect to size, configuration, location, and adjoining habitat and land use. The study utilized a remote photographic method that proved effective and demonstrated that a wide range of native animals will move through a number of different types of underpasses, ranging from small (approximately 1.5 meters diameter) to very large (10 meters diameter). The largest underpass recorded the greatest range of native species, from rats to wombats and wallabies, however, the most frequently used underpass was a 1.5 meter pipe. Introduced animals also use tunnels but, in this study, to a lesser extent than previously speculated. It is concluded, therefore, that underpasses of varying sizes and designs can have a significant role to play in the safe movement of animals across road corridors, but that there are some clear guidelines to be observed in the location, design, and management of these structures to optimize their efficacy.

Noss, R. F. 1990. The ecological effects of roads - or the road to destruction. In: Davis, J., ed. Killing roads: a citizens' primer on the effects and removal of roads. Tucson, AZ: Earth First! Biodiversity Project Special Publication: 1-5.

Noss, R. F. 1993. A conservation plan for the Oregon coast range: some preliminary suggestions. Natural Areas Journal. 13(4): 276-290.
This paper presents a preliminary case study of biodiversity conservation at the scale of a bioregion: the Oregon Coast Range. Goals for the conservation at a regional scale include representation of all ecosystems across their natural range of variability: maintenance of viable populations of all native species; perpetuation of ecological and evolutionary processes; and adaptability to change, both natural and human-induced. Potential reserve locations were determined on the basis of clusters of rare

species and community occurrences, large patches of late-successional forests, and other areas with high spatial overlap of evaluation criteria. Interim management priorities include a moratorium on logging of old growth and other virgin forests, a phasing out of road construction, closures of unnecessary roads, a moratorium on development in natural habitats, initiation of restoration projects, and public education.

Noss, R. F. 1993. Wildlife corridors. In: Smith, D. S.; Hellmund, P. C., eds. Ecology of greenways: design and function of linear conservation areas. Minneapolis, MN: University of Minnesota: 299-309.

Noss, R. F.; Quigley, H. B.; Hornocker, M. G. and others. 1996. Conservation biology and carnivore conservation in the Rocky Mountains. Conservation Biology. 10(4): 949-963.
Large carnivores need large areas of relatively wild habitat, which makes their conservation challenging. These species play important ecological roles and in some cases may qualify as keystone species. Although the ability of carnivores to control prey numbers varies according to many factors and often is effective only in the short term, the indirect effects of carnivores on community structure and diversity can be great. perhaps just as important is the role of carnivores as umbrella species (i.e., species whose habitat area requirements encompass the habitats of many other species). Conservation areas large enough to support populations of large carnivores are likely to include many other species and natural communities, especially in regions such as the Rocky Mountains of Canada and the United States that have relatively low endemism. The application of metapopulation concepts to large carnivore conservation has led to proposals for regional reserve networks composed of wilderness core areas, multiple-use buffer zones, and some form of connectivity. The exceptional vagility of most large carnivores makes such networks feasible in a region with low human population density, such as the Rocky Mountains, but mortality risks still need to be addressed. Roads are a major threat to carnivore recovery because of barrier effects, vehicle collisions, and increased accessibility of wild areas to poachers. Development, especially for tourism, is also becoming a threat in many parts of the region.

O'Gara, B. W.; Harris, R. B. 1988. Age and condition of deer killed by predators and automobiles. Journal of Wildlife Management. 52(2): 316-320.
We evaluated the condition of mule deer and white-tailed deer killed by mountain lions, coyotes, and automobiles from December through March, 1969 to 1981 in western Montana. Predators killed prime-aged animals and automobiles killed ($G=41.4$, $P<0.001$) more fawns and old-aged animals. Fifty-three deer (90%) killed by automobiles were in poor condition, but only two (7%) deer killed by predators were in poor condition. Predator selectivity could not be inferred from the sample of deer killed by automobiles.

O'Neil, T. A.; Witmer, G. W. 1991. Assessing cumulative impacts to elk and mule deer in the Salmon River basin, Idaho. Applied Animal Behaviour Science. 29(1-4): 225-238.

O'Neill, D. H.; Robert, J. R. 1985. Food habits of *Microtus, Peromyscus*, and *Blarina* along Kansas roadsides: cause for caution in roadside contamination studies. Transactions of the Kansas Academy of Science. 88: 40-45.

Oetting, R. B.; Cassel, J. F. 1971. Waterfowl nesting on interstate highway right-of-way in North Dakota. Journal of Wildlife Management. 35: 774-781.
The 789,000 acres of highway right-of-ways in North Dakota provides a substantial amount of waterfowl nesting habitat. They recommend postponing mowing until July 20 to accommodate fledglings.

Ogle, T. W. A.; Wayson, R. L.; Lindeman, W. 1996. Effect of vehicle speed on sound frequency spectra. Transportation Research Record. 1559: 14-25.

Olbrich, P. 1984. A study of the effectiveness of deer warning reflectors and suitability of deer passage corridors. Zeitschrift fur Jagdwissenschaft. 30: 101-116. In German.

Oldham, R. S. 1989. Potential tunnel systems at road developments in England. In: Langton, T. E. S., ed. Amphibians and roads. Proceedings of the toad tunnel conference; 1989 January 7-8; Rendsburg, Federal Republic of Germany. Shefford, England: ACO Polymer Products Ltd.: 155-174.

Ontario Ministry of Transportation and Communication. 1987. Wildlife mitigation survey: Summary report. Ottawa, Ontario: Ontario Ministry of Transportation and Communication. [Pages unknown].

Onyeanusi, Augustine E. 1986. Measurements of impact of tourist off-road driving on grasslands in Masai Mara National Reserve, Kenya: a simulation approach. Environmental Conservation. 13(4): 325-329.

Oosenbrug, S. M.; Mercer, E. W.; Ferguson, S. H. 1991. Moose-vehicle collisions in Newfoundland - management considerations for the 1990's. Alces. 27: 220-225.

Opdam, P.; Van Apeldoorn, R.; Schotman, A.; Kalkhoven, J. 1993. Population responses to landscape fragmentation. In: Vos, C. C.; Opdam, P., eds. Landscape ecology of a stressed environment. London: Chapman and Hall: 147-171.

Opdam, P.; Foppen, R.; Reijnen, R.; Schotman, A. 1994. The landscape ecological approach in bird conservation: integrating the metapopulation concept into spatial planning. Ibis. 137:S139-S146.
In the Netherlands, fragmentation of (semi)natural ecosystems is regarded as a major nature conservation problem. The current Dutch Nature Conservation Policy Plan proposes a spatial network consisting of existing nature reserves, nature redevelopment areas and corridor zones. In this contribution we show that breeding birds are affected by the spatial distribution of their habitat.

Osawa, R. 1989. Road kills of the swamp wallaby (*Wallabia bicolor*) on North Stradbroke Island, southeast Queensland, Australia. Australian Wildlife Research. 16: 95-104.

Ostfeld, R. S.; Manson, R. H. 1996. Long-distance homing in meadow voles, *Microtus pennsylvanicus*. Journal of Mammalogy. 77(3): 870-873.
During a field experiment on density-dependent processes in meadow voles (*Microtus pennsylvanicus*), we removed 848 voles from field enclosures and released them 1,200 meters away. Eleven animals (1.3%) returned to the enclosure from which they had been removed, which entailed traversing inhospitable habitat (forest, wetland), obstacles (permanent stream, roads), and climbing a 0.9-m hardware-cloth fence surrounding the enclosures. For 6 of the 11 voles, returning home was accomplished in > 2 but < 4 weeks; the others returned in # 2 weeks. Voles returning home, which averaged ca. 30 g, lost on average 5.3% of their body mass during homing, unlike their resident counterparts, which gained mass. The voles that homed could not have used familiar objects as cues for navigation, but whether they used distant points of reference or wandered randomly is unknown. Our findings suggest that meadow voles are capable of travelling > 1 kilometer toward home, and thus, it is likely that they could travel similar distances while dispersing.

Oxley, D. J.; Fenton, M. B.; Carmody, G. R. 1974. The effects of roads on populations of small mammals. Journal of Applied Ecology. 11: 51-59.
The authors found that road crossing decreased with increased road clearance width and mortality with increased road clearance width. They found evidence of barrier effect even for lightly used roads. They suggest that divided highways with clearances of 90 meters or more may be as effective barriers to the dispersal of small forest mammals as bodies of fresh water twice as wide.

Oxley, D. J.; Fenton, M. B. 1976. The harm our roads do to nature and wildlife. Canadian Geographic Journal. 92(3): 40-45.

Pafko, F.; Kovach, B. 1996. Minnesota experience with deer reflectors. In: Evink, G.; Ziegler, D.; Garrett, P.; Berry, J., eds. Transportation and wildlife: reducing wildlife mortality and improving wildlife

passageways across transportation corridors: Proceedings of the Florida Department of Transportation/Federal Highway Administration transportation-related wildlife mortality seminar; 1996 April 30-May 2; Orlando, FL. FHWA-PD-96-041. Washington, DC: U.S. Department of Transportation, Federal Highway Administration: 116-124.
Deer/vehicle accidents estimated to range from 12,000 to 16,000 per year. Economic impact of roadkill deer estimated at 35 million dollars per year. Accident rates were reduced after installation of reflectors in northern coniferous forest, central hardwoods, and farmland habitats. Installations in suburban areas had increased accident rates.

Palis, J. G. 1994. *Rana utricularia* (southern leopard frog) road mortality. Herpetological Review. 25(3): 119-122.

Palman, D. S. 1977. Ecological impact of Interstate 95 on small and medium sized mammals in northern Maine. Orono, ME: University of Maine. [Pages unknown]. M.S. thesis.
Cited in Hubbs and Boonstra 1995, p. 13, regarding higher diversity of small mammals and birds within the roadway corridor.

Palman, D. S.; Richens, V. B. 1979. Effects of Interstate 95 on small and medium-sized mammals in northern Maine. Orono, ME: University of Maine, Life Sciences and Agricultural Experimental Station; No. 26. 21 p.
Cited in Hubbs and Boonstra 1995, p. 13, regarding no difference in diversity of small mammals and birds within the roadway corridor compared to interior forest.

Palomo-Ferrer, J. J. 1992. Provisional report of the mortality of vertebrates on the roads of Castellon, September 1991. In: Lopez, Redondo, ed. I jornadas para el estudio y prevencion de la mortalidad de vertebrados en carreteras, Madrid, 5 y 6 de Octubre de 1991. Tomo 2. [Sessions in the study of prevention of road mortalities of vertebrates, Madrid, 5 and 6 October, 1991. Volume 2.]. Ambiental, Madrid: Coordinadora de Organizacciones de Defensa: 195-211.

Panetta, F. D. 1991. Negative values of corridors. In: Saunders, D. A.; Hobbs, R. J., eds. Nature conservation 2: the role of corridors. Chipping Norton, Australia: Surrey Beatty and Sons:

Paquet, P. C. 1993. Ecological studies of recolonizing wolves in the central Canadian Rocky Mountains - summary reference document. Canmore, Alberta: John/Paul and Associates. 219 p.

Paquet, P. C.; Gibeau, M.; Herrero, S. and others. 1994. Wildlife corridors in the Bow River Valley, Alberta. Canmore, Alberta: Wildlife Corridor Task Force 37 p.

Paquet, P. C.; Hackman, A. 1995. Large carnivore conservation in the Rocky Mountains: a long-term strategy for maintaining free-ranging and self-sustaining populations of carnivores. Toronto, Ontario: World Wildlife Fund-Canada 53 p.

Paquet, P. C.; Callahan, C. 1996. Effects of linear developments on winter movements of gray wolves in the Bow River Valley of Banff National Park, Alberta. In: Evink, G.; Ziegler, D.; Garrett, P.; Berry, J., eds. Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors: Proceedings of the Florida Department of Transportation/Federal Highway Administration transportation-related wildlife mortality seminar; 1996 April 30-May 2; Orlando, FL. FHWA-PD-96-041. Washington, DC: U.S. Department of Transportation, Federal Highway Administration: 46-66.
The authors used snow tracking and telemetry to determine encounter rate and response to barriers. They used raked sand track traps to document use of crossing structures and telemetry to determine use of buffer zones adjacent to highway. Highway 1A and the railroad were nearly transparent to wolf movement. The Trans-Canada highway was a significant barrier, with 14 crossings in four years. Use of underpasses was variable. Rather than being barriers to wolf movement the powerline and railway

seem to redirect wolf movements because the wolves follow them. Habituation and social transmission of information probably are important in establishing consistent usage of underpasses.

Paquet, P. C.; Wierzchowski, J.; Callaghan, C. 1996. Effects of human activity on gray wolves in the Bow River Valley, Banff National Park, Alberta. In: Green, J.; Pacas, C.; Cornwell, L.; Bayley, S., eds. Ecological outlooks project. A cumulative effects assessment and futures outlook of the Banff Bow Valley. Prepared for the Banff Bow Valley Study. Ottawa, Ontario: Department of Canadian Heritage: 7-1. Chapter 7.
Twice in this century, gray wolves were eliminated from the Bow River Valley of Banff National Park by large scale extermination. Recently, wolves increased in numbers and recolonized areas from which they had been eliminated. Most wolves living in the Bow Valley occupy a shrinking natural environment. The effectiveness of the landscape to support wolves has been reduced by the loss, alienation, and alteration of key habitat. Wolves have been physically displaced, partially alienated, or blocked from using a minimum of 92 squared kilometers of the Bow Valley's mountain habitat (62% of the best wolf habitat). Ranges are dissected by highways, secondary roads, railways, and powerlines. Barriers such as highways and railways amplify the landscape-related problems because they are direct, and increasingly important, causes of mortality for wolves. Highway and railway collisions accounted for 76% of wolf mortality in the Bow Valley. Development planned for recreation areas and transportation corridors will further degrade habitat deemed to be important for wolves.

Paquet, P. C.; Wierczhowski, J.; Callaghan, C. 1996. Summary report on the effects of human activity on gray wolves in the Bow River Valley, Banff National Park, Alberta. Alberta, Canada: Banff National Park Warden Service 126 p.

Parr, T. W.; Way, J. M. 1988. Management of roadside vegetation: the long-term effects of cutting. Journal of Applied Ecology. 25(3): 1073-1087.

Pascasio-Lopez, J. M. 1992. Provisional report of the mortality of vertebrates on the roads of Cartagena, September 1991. In: Lopez, Redondo, ed. I jornadas para el estudio y prevencion de la mortalidad de vertebrados en carreteras, Madrid, 5 y 6 de Octubre de 1991. Tomo 2. [Sessions in the study of prevention of road mortalities of vertebrates, Madrid, 5 and 6 October, 1991. Volume 2.]. Ambiental, Madrid: Coordinadora de Organizacciones de Defensa: 180-187.

Patten, Robbin B.; Benjamin, H. B. 1980. A rattlesnake (*crotalus ruber*) feeds on a road-killed animal. Journal of Herpetology. 14(1): 111-112.

Patten, Robbin B. 1981. Author's reply on road killed dipodomys. Journal of Herpetology. 15(1): 126-128.

Pauli, B. 1997. Effects of highway salting on amphibians. Ottawa, Ontario: Environment Canada. [Pages unknown].

Pedersen, R. J. 1979. Management and impacts of roads in relation to elk populations. In: Conference proceedings: recreational impact on wildlands; 1978 October 27-29; Seattle, Washington. R-6-001-1979. Portland, OR: U.S. Department of Agriculture Forest Service, Pacific Northwest Region: 169-173.

Pedevillano, C.; Wright, R. G. 1987. The influence of visitors on mountain goat activities in Glacier National Park, Montana. Biological Conservation. 39: 1-11.
Information on human/wildlife interactions and wildlife viewing habits is essential to park management. To help fulfil this need, mountain goat behavior and use of specially constructed highway underpasses and an adjacent mineral lick were monitored simultaneously with visitor activities at an observation area in Glacier National Park, Montana. We found that, although the site was very popular with park visitors, those using the observation area did not appear to have an adverse effect on mountain goat use of the mineral lick. Traffic on the highway and visitors standing above the underpasses did, however, influence behaviour of mountain goats crossing the highway,

causing run backs, hesitation, and eliciting visual alarm responses. The relatively short time-period visitors spent at the site was also noted and suggestions are made for improving the education value of the area as well as minimizing the problems which occur at the underpasses.

Peek, F.; Bellis, E. D. 1969. Deer movements and behavior along an interstate highway. Highway Research News. 36: 36-42.

Pennsylvania Game Commission. 1985. 1984 recorded highway mortality: deer and bear. Pennsylvania Game News. June: 40-41.

Penny, Anderson A. 1994. Roads and nature conservation: guidance on impacts, mitigation and enhancement. Peterborough, U.K.: English Nature. 81 p.

Persson, T. S. 1995. Management of roadside verges: vegetation changes and species diversity. Sveriges Lantbruksuniversitet Institutionen for Ekologi och Miljovard Rapport. 1-213.

Peterson, Ronald P. 1987. A new bluebird nesting structure for highway rights-of-way. Wildlife Society Bulletin. 15(2): 200-204.

Pfeifer, M. 1997. Barrier effect of highways and express roads on wildlife. Stelemark, Austria: Landesjagerschaft; Unpublished report. [Pages unknown].

Pfister, H.; Keller, V. 1995. Roads and wildlife - are green bridges a solution? Bauen. 1: 26-30.

Pils, C. M.; Martin, M. A. 1979. The cost and chronology of Wisconsin deer-vehicle collisions. [Location of publisher unknown]: Wisconsin Department of Natural Resources; Res. Rep. 103. 5 p.

Plumpton, D. L.; Lutz, R. S. 1993. Influence of vehicular traffic on time budgets of nesting burrowing owls. Journal of Wildlife Management. 57(3): 612-616.
Adult burrowing owls (*Speotyto cunicularia*) commonly nest near roads on the Rocky Mountain Arsenal (RMA), Colorado, and had the potential to be disturbed during environmental clean-up operations. Thus, we characterized time-budgets of adults during 1990 to 1991 to determine potential impacts of environmental cleanup traffic on their nesting behavior. Males and females differed in time spent resting (P less-than-or-equal-to 0.01), alert (P = 0.002), and out-of-sight (P = 0.004) in the pre-hatch season. From pre- to post-hatch seasons, male alert behavior decreased, while time spent out-of-sight increased (P = 0.0001). Female alert behavior increased, while out-of-sight behaviors decreased (P = 0.0001). Vehicular disturbance observed in this study (0-16 vehicles/15 min) was only weakly correlated to two of eight behaviors (locomotion and alert). Vehicular traffic, our index of cleanup disturbance, therefore had little impact on nesting burrowing owl behavior, and it had no impact on productivity even though nesting locations placed them in close proximity.

Plumpton, D. L.; Lutz, R. S. 1993. Nesting habitat use by burrowing owls in Colorado. Journal of Raptor Research. 27: 175-179.
Habitats used by nesting burrowing owls (*Speotyto cunicularia*), and the fidelity shown to traditionally used nesting areas were studied in 1990 and 1991. Nesting burrowing owls (N = 47 pairs) occupied burrows with a shorter distance to the nearest road, and shorter grass and forb height (P < 0.005) than generally available, while using black-tailed prairie dog (*Cynomys ludovicianus*) towns with greater burrow density, nearest perch distance, and percentage of bare ground (P < 0.05) than available. Of adults banded in 1990, 39% returned in 1991, while only 5% of chicks banded in 1990 returned. Of returning adults, 66% reused the same prairie dog town used the prior year. From 1990 to 1991, 90% of prairie dog towns were reused (N = 18), and 20% of nesting burrows (N = 4) were reused. Burrowing owls exhibited a strong fidelity to previously used nesting towns, and were moderately site-specific in nesting habitat requirements.

Podloucky, R. 1989. Protection of amphibians on roads - examples and experiences from Lower Saxony. In: Langton, T. E. S., ed. Amphibians and roads. Proceedings of the toad tunnel conference; 1989 January 7-8; Rendsburg, Federal Republic of Germany. Shefford, England: ACO Polymer Products Ltd.: 15-28.

Pojar, T. M.; Reed, D. F.; Reseigh, T. C. 1972. Highway construction; motorist and deer safety. Proceedings of the Western Association of State Game and Fish Commissions. 52: 268-271.

Pojar, T. M.; Prosence, R. A.; Reed, D. F.; Woodard, T. N. 1975. Effectiveness of a lighted, animated deer crossing sign. Journal of Wildlife Management. 39: 87-91.
Two lighted, animated deer crossing signs were installed adjacent to Highway 82 south of Glenwood Springs, Colorado, delineating a 1.61 kilometer (1 mi.) segment of highway where deer-vehicle accidents frequently occurred. The signs were turned on and off for alternate weekly periods of 1972 and 1973 during the times when most deer-auto accidents were expected to occur. Numbers of deer crossing the highway were estimated and all deer-vehicle accidents were documented. The number of crossings per deer killed on the highway was 56.9:1 and 56.5:1 with the sign on and with the signs off, respectively. There was no difference in the ratios (P>0.50). Mean vehicle speeds were lower (P<0.50) with the signs on but the reduction in speed was less than 4.83 kilometers per hour (3.0 mph). When three deer carcasses were placed along the highway with the signs on, the mean vehicular speed dropped 10.09 kilometers per hour (6.27 mph). With the signs off the difference was 12.63 kilometers per hour (7.85 mph). There was no significant difference in the mean speeds (P>0.50) when dead deer were on the highway whether the signs were on of off. Apparently motorists did see the sign, but their response in the form of speed reduction or increased awareness was not sufficient to affect the crossings per kill ratio.

Pollard, R. H.; Ballard, W. B.; Noel, L. E.; Cronin, M. A. 1996. Parasitic insect abundance and microclimate of gravel pads and tundra within the Prudhoe Bay oil field, Alaska, in relation to use by caribou, *Rangifer tarandus granti*. Canadian Field Naturalist. 110(4): 649-658.
During the post-calving period (late June-early August), Caribou (*Rangifer tarandus granti*) movements, distribution, and behavior are significantly influenced by harassment from parasitic insects such as mosquitoes (*Aedes* spp.) and oestrids (warble fly [*Hypoderma tarandi*] and nose bot fly [*Cephenomyia trompe*]). A number of studies have mentioned that Caribou use oil field infrastructure features such as gravel pads and roadbeds during insect harassment but there has been no effort to quantify factors contributing to this behavior. During 1992 and 1993 parasitic insect abundance and several weather parameters were measured on active and inactive gravel drilling pads, and undisturbed adjacent tundra in the Prudhoe Bay oil field, Alaska, in an effort to explain use of these man-made structures by Caribou. Ambient air temperatures were lower on gravel pads than adjacent tundra at inactive pads but not at active pad sites. Wind velocities were higher on inactive and active pads than on adjacent tundra. Mosquitoes were more abundant on tundra than gravel pads at both active and inactive sites. Mosquito abundance was positively correlated with temperature and negatively correlated with wind velocity and relative humidity at both inactive and active gravel pads. During periods of high insect harassment Caribou were observed using both active and inactive gravel pads.

Pollard, R. H.; Ballard, W. B.; Noel, L. E.; Cronin, M. A. 1996. Summer distribution of caribou, *Rangifer tarandus granti*, in the area of the Prudhoe Bay oil field, Alaska, 1990-1994. Canadian Field Naturalist. 110(4): 659-674.
Aerial surveys were conducted within the Prudhoe Bay oil field area in northern Alaska during 1990 to 1994 to document summer distribution of Caribou (*Rangifer tarandus granti*). Numbers of Caribou observed per survey ranged from 34 to 13,058. When insect activity was moderate to high, more Caribou were observed within the oil field than when insect activity was low. Severe mosquito (*Aedes* spp.) harassment often resulted in large post-calving aggregations of Caribou in coastal areas; When mosquito harassment subsided, aggregations often moved inland through the oil field or laterally along the coast. On several occasions, large groups of Caribou (2,000 to 4,000 individuals) were observed feeding or bedded down in the central portion of the oil field. Caribou were observed on, and used, oil field gravel pads and roads as insect relief habitat during the mosquito season in late June through mid-

July, and also used the shade of oil field structures when oestrid flies (*Hypoderma tarandi* and *Cephenomyia trompe*) were abundant from mid-July to early August. Five years of observations document that Caribou use habitat within and travel through oil fields during summer during periods of high insect activity.

Port, G. R.; Thompson, J. R. 1980. Outbreaks of insect herbivores on plants along motorways in the United Kingdom. Journal of Animal Ecology. 17: 649-656.

Portillo, M. M. 1992. Provisional report of the mortality of vertebrates on the roads of Sevilla, September 1991. In: Lopez, Redondo, ed. I jornadas para el estudio y prevencion de la mortalidad de vertebrados en carreteras, Madrid, 5 y 6 de Octubre de 1991. Tomo 2. [Sessions in the study of prevention of road mortalities of vertebrates, Madrid, 5 and 6 October, 1991. Volume 2.]. Ambiental, Madrid: Coordinadora de Organizacciones de Defensa: 97-100.

Puchlerz, T.; Servheen, C. 1994. Grizzly bear/motorized access management. Missoula, MT: U.S. Fish and Wildlife Service; Interagency Grizzly Bear Committee Taskforce Report. 7 p.

Puglisi, M. J.; Lindzey, J. S.; Bellis, E. D. 1974. Factors associated with highway mortality of white-tailed deer. Journal of Wildlife Management. 38: 799-807.
During 18 months 874 white-tailed deer were killed by vehicles on the 313 mile length of Pennsylvania Interstate 80. Male and female mortality was generally similar; however, during December male mortality decreased while female mortality remained essentially stable. The location of highway fencing was the most significant of the factors studied. Generally, high deer mortality occurred where the fence was located at the edge of a wooded area or within 25 yards of the nearest wooded area. The lowest deer mortality occurred where the fence was located within the woods. The effect of vegetation on deer mortality was significant only where fencing was absent.

Puglisi, M. J. 1974. Pennsylvania conducts study of 1974 vehicle-deer collisions. Traffic Safety. 74: 25-29.

Puky, M. 1987. Toads on roads campaign - Hungary. Herpetofauna News. 1987: 3-5.

Putman, R. J. 1997. Deer and road traffic accidents - options for management. Journal of Environmental Management. 51(1): 43-57.
Statistics from the U.S. or from Continental Europe suggest that damage to persons and property arising from road or railway accidents involving deer amounts to a very significant annual total and is increasing everywhere. Despite this, the relative efficacy or cost-effectiveness of different control options is poorly understood. This review presents an analysis of deer movement patterns in relation to roads in order to try and develop some general conclusions about the probable or expected pattern and behaviour of road crossings. Based on such framework the various possible options available for reducing accident rates are more formally evaluated. The review focuses primarily on deer and roadside management within Europe. Approaches to the management of deer on roads consist either of methods to increase driver awareness of deer (deer warning signs) and/or methods to reduce deer crossing activity or change the pattern of crossings (fences, reflectors or chemical repellents). Effective reduction of deer road-crossings can only be assured in erection of a genuinely impermeable barrier fence. Cost considerations usually result in erection of barriers which are only partially effective. Such fencing must be viewed merely as a deterrent to crossing and not an absolute barrier; effectiveness can be enhanced by providing alternative means of passage, thus reducing the probability of deer intent on crossing, forcing the fence. Some means of exit (one-way gates, deer-leaps) should be provided for animals that do get on to the carriageway and are then unable to escape. Provision of fencing, with the additional structures of one-way gates and underpasses, is likely to be extremely costly; such high costs may only be justified in regard to major roads. For minor roads where traffic flow is lighter and intermittent, deer-mirrors or game-reflectors are a more economical and a more appropriate solution, since the intention is to delay crossing, rather than prevent it. The effectiveness of both fencing and

mirrors may be reinforced in especially sensitive areas by erection of appropriate road signs to increase driver awareness.

Quarles, H. D.; Hanawalt, R. B.; Odum, W. E. 1974. Lead in small mammals, plants, and soil at varying distances from a highway. Journal of Applied Ecology. 11: 937-949.

Queal, L. M. 1968. Effectiveness of roadside mirrors in controlling deer-car accidents. Lansing, MI: Michigan Department of Natural Resources; Research and Development Report No. 137. 143 p.

Quene, E.; Grotenhuis, J. 1994. Bird casualties on roads in the province of Drenthe: an update. Drentse Vogels. 1994: 73-81.

Quinn, J. F.; Hastings, A. 1987. Deer-vehicle accidents. Colorado Game Research Review. 7: 8-12.

Ranney, J. W.; Brunner, M. C.; Levenson, J. B. 1981. The importance of edge in the structure and dynamics of forest islands. In: Burgess, R. L.; Sharpe, D. M., eds. Forest island dynamics in man-dominated landscapes. New York: Springer-Verlag. [Pages unknown]:

Ratcliffe, E. J. 1974. Wildlife considerations for the highway designer. Journal of the Institute of Municipal Engineers. 101: 289-294.
Summarized in Foster and Humphrey 1992, this is a popular article describing crossing structures for badgers.

Ratcliffe, J. 1983. Why did the toad cross the road? Wildlife (London). 5(8): 304-307.

Ratcliffe, J. 1984. Wildlife and highways. Highways and Transportation. 31(11): 19-21.
The paper draws attention to the need to consider wildlife in highway design, and is introduced by a description of one of the first provisions made for wildlife on a motorway. The need for wildlife surveys at the planning stage is followed by examples of animals likely to be affected and what can be done for each species. Habitat improvement is dealt with and the conclusion gives a brief code for the highway engineer.

Reading, C. J. 1989. Opportunistic predation of common toads (*Bufo bufo*) at a drift fence in southern England. In: Langton, T. E., ed. Amphibians and roads. Proceedings of the toad tunnel conference; 1989 January 7-8; Rendsburg, Federal Republic of Germany. Shefford, England: ACO Polymer Products Ltd.: 105-112.

Reading, R. P.; Matchett, R. 1997. Attributes of black-tailed prairie dog colonies in north central Montana. Journal of Wildlife Management. 61(3): 664-673.
We examined several characteristics of black-tailed prairie dog (*Cynomys ludovicianus*) colonies in Phillips County, Montana, including slope, aspect, soils, land tenure, and distance from roads using a geographic information system (GIS). Colonies exhibited significantly smaller slopes, but not significantly different aspects than did randomly located polygons. In addition, colonies were more prevalent than expected on well drained clay-loam and loam soils and on U.S. Bureau of Land Management (BLM) laud than on other soil types or on private land. Although prairie dogs commonly use roads for dispersal, distance to nearest road was not related to prairie dog density nor to colony area. These findings could be used to develop a cartographic model of preferred black-tailed prairie dog habitat useful for prairie dog monitoring and management, and for estimating prairie dog expansion potential for possible black-footed ferret (*Mustela nigripes*) reintroduction sites.

Reck, H.; Kaule, G. 1993. Roads and habitats: an analysis of the effects due to roads on plants, animals and their habitats. Stuttgart, Germany: Institut fur landschaftsplanung und okologie, Universitat Stuttgart. [Pages unknown].

Reed, D. F. 1971. Deer-elk investigations: deer underpass evaluation. Denver, CO: State of Colorado, Game, Fish, and Parks Department 10 p.

Reed, D. F.; Pojar, T. M.; Woodard, T. N. 1974. Mule deer responses to deer guards. Journal of Range Management. 27: 111-113.
Summarized in Foster and Humphrey 1992, they found deer guards modeled after cattle guards were not effective.

Reed, D. F.; Pojar, T. M.; Woodard, T. N. 1974. Use of one-way gates by mule deer. Journal of Wildlife Management. 38: 9-15.

Reed, D. F.; Woodard, T. N.; Pojar, T. M. 1975. Behavioral response of mule deer to a highway underpass. Journal of Wildlife Management. 39: 361-367.

Reed, D. F. 1976. Deer-auto accident investigations: evaluation of deer underpasses. Denver, CO: State of Colorado, Division of Wildlife 6 p.

Reed, D. F.; Woodard, T. N.; Beck, T. D. 1977. Highway lighting to prevent deer-auto accidents. Denver, CO: State of Colorado, Division of Highways, Division of Wildlife; CDOH-P/R-R-77-5; FHWA/CO-77-5. 35 p.
Deer vehicle accidents have been the cause of considerable property damage and the loss of biotic resources. This is especially the case in rural areas in mountainous terrain where nighttime driver visibility is poor. The purpose of this research was to determine if deer-vehicle accidents were affected by fixed highway illumination. This was done by comparing responses of motorists to deer on the highway and deer responses to the motorists, with and without fixed illumination. Estimated deer crossings per kill was 9.7% higher with the lights on compared to lights off. When a deer simulation was present under lighted conditions mean vehicle speeds decreased by 13.9 kilometers (8.6 mi.) per hour with brake lights observed on 50.6% of the approaching vehicles. The Roadway Lighting Committee (1972) recommends lighting standards based on mean horizontal illumination and illumination uniformity ratios for different roadway and area classifications.

Reed, D. F. 1979. Deer-auto investigations: deer vehicle accidents statewide and methods and devices to reduce them. Denver, CO: State of Colorado, Division of Wildlife; Colo. W-125-R-5/Wk.P1.01/Job 01. 21 p.

Reed, D. F.; Woodard, T. N.; Beck, T. D. 1979. Regional deer-vehicle research. Denver, CO: State of Colorado, Division of Wildlife. [Pages unknown].

Reed, D. F. 1981. Mule deer behavior at a highway underpass exit. Journal of Wildlife Management. 45: 542-543.
Summarized in Foster & Humphrey 1992. An additional 6 years of monitoring at the underpass in Reed et al. (1975) showed that about 75% of the mule deer exiting the structure were reluctant. wary, or frightened. Behavioral responses of deer to the underpass did not change substantially over 10 years. A larger structure probably would have resulted in fewer vehicular accidents and deer deaths (the monitored structure was a 3.05 x 3.05 m concrete box underpass, 30.48 m long).

Reed, D. F.; Woodard, T. N. 1981. Effectiveness of highway lighting in reducing deer-vehicle accidents. Journal of Wildlife Management. 39: 361-367.
Many studies have found that the majority of deer vehicle collisions occur between dusk and dawn. This study tested the hypothesis that highway lighting is an effective method for reducing deer-vehicle accidents. Lights were installed on about 1.2 kilometers of highway and turned on and off at 1 week intervals for 5 years. Highway lighting did not affect the location of deer crossings or accident locations.

Reed, D. F.; Beck, T.; Woodard, T. N. 1982. Methods of reducing deer-vehicle accidents: benefit cost analysis. Wildlife Society Bulletin. 10(4): 349-354.
Benefit-cost (B:C) analysis was used to describe the cost efficiency of 2.4 meter fencing and associated structures designed to reduce deer-vehicle accidents. B:C ratios for six, 2.4 meter fences ranged from 2.59:1 to 12.37:1. Using a hypothetical fence model sensitivity analyses were conducted on cost of vehicle repair, value of deer, pre-fence mortality (dead deer), fence effectiveness, discount rate, cost of fence, and cost of fence maintenance. B:C ratios were calculated for three fence designs when varying pre-fence mortality (accidents/1.6 km/year) and when keeping most of the other values constant in the model. Considering a minimum B:C ratio of 1.36:1, 8, 16 and 24 dead deer/1.6 km/year were the minimums for justifying 2.4 meter fencing on one side of the highway, on both sides, and on both sides with an underpass, respectively.

Reed, R. A.; Johnson-Barnard, J.; Baker, W. L. 1996. Contribution of roads to forest fragmentation in the Rocky Mountains. Conservation Biology. 10(4): 1098-1106.
The contribution of roads to forest fragmentation has not been adequately analyzed. We quantified fragmentation due to roads in a 30,213-13-hectare section of the Medicine Bow-Routt National Forest in south-eastern Wyoming with several indices of landscape structure using a geographic information system. The number of patches, mean patch area, mean interior area, mean area of edge influence, mean patch perimeter, total perimeter, and mean patch shape identified patch- and edge-related landscape changes. Shannon-Wiener diversity, dominance, contagion, contrast, and angular second moment indicated effects on landscape diversity and texture. Roads added to forest fragmentation more than clearcuts by dissecting large patches into smaller pieces and by converting forest interior habitat into edge habitat. Edge habitat created by roads was 1.54-1.98 times the edge habitat created by clearcuts. The total landscape area affected by clearcuts and roads was 2.5-3.5 times the actual area by these disturbances. Fragmentation due to roads could be minimized if road construction is minimized or rerouted so that its fragmentation effects are reduced. Geographic information system technology can be used to quantify the potential fragmentation effects of individual roads and the cumulative effects of a road network on landscape structure.

Reeves, A. F.; Anderson, S. H. 1993. Ineffectiveness of Swareflex reflectors at reducing deer-vehicle collisions. Wildlife Society Bulletin. 21: 349-354.
Reflectors were installed along a 3.2 kilometer segment of road and monitored for 3 years. The reflectors were covered and uncovered at 1 or 2 week intervals. The number of deer killed by vehicles while the reflectors were uncovered and operative exceeded the number of mortalities expected because of chance. No evidence indicated that Swareflex reflectors had any effect in reducing mule deer vehicle collisions. They observed fewer deer killed than expected in the test section when reflectors were uncovered only during the first year of the study. They suggest that deer may respond to reflectors only when they present novel stimuli.

Reh, W. 1989. Investigations into the influence of roads on the genetic structure of populations of the common frog (*Rana temporaria*). In: Langton, T. E., ed. Amphibians and roads. Proceedings of the toad tunnel conference; 1989 January 7-8; Rendsburg, Federal Republic of Germany. Shefford, England: ACO Polymer Products Ltd.: 101-103.

Reh, W.; Seitz, Z. 1990. The influence of land use on the genetic structure of populations of the common frog (*Rana temporaria*). Biological Conservation. 54: 239-249.
In order to find out the influence of land use and topographic distance on the genetic structure of populations of the common frog in the Saar-Palatinate lowlands (Germany), tissue of larvae was examined by means of horizontal starch gel electrophoresis. A total of 24 loci coding for 14 different enzymes were studied. Genotype frequencies, allele frequencies and mean heterozygosity were calculated, and genetic distances using Nei's formula. Strong deviations from the Hardy-Weinberg equilibrium were found; the degree of homozygosity was higher than expected. Separation by highways reduced average heterozygosity as well as genetic polymorphism of local populations. One area surrounded by roads had high genetic distances to other sampling stations. A multiple regression

analysis showed that motorways and railways have a significant (P=0.03) barrier effect on frog populations within 3 to 4 kilometers. Meadowland apparently enabled individual exchange in a range between 2 and 7 kilometers. Consequences for the design of biotope systems are discussed.

Reichholf, J. 1986. Population dynamics of domestic cats (*felis sylvestris catus*) in southeastern Bavaria: results of 10 years of road kill statistics. Saeugetierkd. Mitt. 33(2&3): 264-266.

Reichholf, Josef. 1983. Is there an influence of the traffic-caused road mortality on the population dynamics of the European hedgehog (*Erinaceus europaeus*)? Spixana. 6(1): 87-91.

Reid, J. W.; Bowles, I. A. 1997. Reducing the impacts of roads on tropical forests. Environment. 39(8):10.

Reijnen, R.; Thissen, J. B.; Bekker, G. J. 1987. Effects of road traffic on woodland breeding bird populations. Acta Oecologia Generalis. 8(2): 312-313.

Reijnen, R.; Foppen, R. 1991. Effect of road traffic on the breeding site-tenacity of male willow warblers (*Phylloscopus trochilus*). Netherlands: Journal of Ornithology. 132(3): 291-295.

Reijnen, R.; Foppen, R. 1994. The effects of car traffic on breeding bird populations in woodland. I. Evidence of reduced habitat quality for willow warblers (*Phylloscopus trochilus*) breeding close to a highway. Journal of Applied Ecology. 31: 85-94.
This study investigated the effect of a highway with dense traffic on the quality of adjacent habitats for the willow warbler (*Phylloscopus trochilus*). In the zone of 0-200 meters from the highway (road zone) the density of territorial males was much lower (2.1/ha) than in zones with a comparable habitat at a greater distance (3.3/ha). The lower density in the road zone was due to a low presence of older males. As a consequence, the proportion of yearling males in the road zone was about 50% higher than in the other zones. Yearling males occupied their territories in the road zone later than in the other zones. In the road zone the proportion of successful yearling males was about 50% lower than in the other zones. No difference was observed in the number of nestlings per male. In the road zone the total annual output of males per ha was about 40% lower than in the other zones. The road zone probably acts as a sink for males immigrating from the intermediate and control zones. A possibly important cause of the reduced habitat quality in the road zone is the noise. There is much evidence that the highway reduced the population size of the whole study area (165 ha of which about 20% belonged to the road zone).

Reijnen, R.; Foppen, R. 1995. The effects of car traffic on breeding bird populations in woodland. IV. Influence of population size on the reduction of density close to a highway. Journal of Applied Ecology. 32(3): 481-491.
This study tested the assumption that in years with a low overall population size the density-depressing effect of roads on breeding birds will be more important than in years with a high overall population size. The effect on the density was investigated in 1984, 1986 and 1988. Of the 23 species that could be analysed each year, 17 species had a lowered density close to the road in at least 1 year. In 1984 and 1986 the number of affected species was much higher (10 and 14, respectively) than in 1988 (4). The number of affected species, as well as the effect size for all species combined and for most individual species, was negatively correlated with the overall population size. It is concluded that in years with a high-overall population size, the use of density as a response variable will cause a considerable underestimation of the reduction of the habitat quality close to roads. This has not been recognized well in impact studies concerning road traffic, nor in other impact studies.

Reijnen, R.; Foppen, R.; Terbraak, C.; Thissen, J. 1995. The effects of car traffic on breeding bird populations in woodland. III. Reduction of density in relation to the proximity of main roads. Journal of Applied Ecology. 32(1): 187-202.
This study investigated the effect of car traffic on the breeding density of birds in deciduous and coniferous woodland, and the importance of noise and visibility of cars as possible factors affecting density. Of the 43 species analysed in both woodland types, 26 species (60%) showed evidence of

reduced density adjacent to roads (based on analysis with Wilcox on signed-ranks test and regression). Regression models with noise load as the only independent variable gave the best overall results. Calculated 'effect distances' (the distance from the road up to where a reduced density was present) based on these regressions varied between species from 40 to 1500 meters for a road with 10,000 cars per day to 70 to 2800 meters for a road with 60,000 cars per day (120 km h(-1)) and 70% amount of woodland along the road). For a zone of 250 meters from the road the reduction of the density varied from 20 to 98%. When visibility of cars was controlled for, the number of species showing density reductions was much higher on plots with a high noise load than on ones with a low noise load. When noise conditions were held constant, however, there was no difference in bird densities between plots with high and low visibility of cars. It is argued that noise load is probably the most important cause of the reduced densities, Visibility of cars, direct mortality and pollution are considered unimportant. The results of this study stress the importance of considering the effect of car traffic on the breeding density of birds in planning and constructing main roads.

Reijnen, R.; Foppen, R.; Meeuwsen, H. 1996. The effects of traffic on the density of breeding birds in Dutch agricultural grasslands. Biological Conservation. 75: 255-260.
The effect of traffic on the breeding density of grassland birds was studied in 1989 in 15 transects along main roads in The Netherlands. Out of 12 species that could be analysed, seven showed a reduced density adjacent to the road. There was also a strong effect on the summed densities of all species. Disturbance distances varied between species, ranging from 20 to 1700 meters from the road at 5,000 cars a day and from 65 to 3530 m at 50,000 cars a day (car speed 120 km/h). At 5,000 cars a day most species had an estimated population loss of 12 to 56% within 100 meters of roads, but beyond 100 meters > 10% loss only occurred in black-tailed godwit (*Limosa limosa*) (22% for 0-500 m zone) and oystercatcher (*Haematopus ostralegus*) (44% up to 500 m and 36% for 0-1500 m zone). At 50,000 cars a day all species had estimated losses of 12-52% up to 500 meters while lapwing (*Vanellus vanellus*), shoveler (*Anas clypeata*), skylark (*Alauda arvensis*), black-tailed godwit and oystercatcher populations were reduced by 14 to 44% up to 1500 meters. In The Netherlands, with a dense network of extremely crowded motorways, traffic should be considered a serious threat to breeding bird populations in grasslands. Greater care should be taken in planning new roads, and it is important to explore how the present effects can be reduced. Noise is probably the primary factor causing reduced bird density.

Reijnen, R.; Foppen, R.; Veenbaas, G. 1997. Disturbance by traffic of breeding birds - evaluation of the effect and considerations in planning and managing road corridors. Biodiversity and Conservation. 6(4): 567-581.
In wildlife considerations in planning and managing road corridors little attention has been given to the effects of disturbance by traffic on populations of breeding birds. Recent studies, however, show evidence of strongly reduced densities of many species of woodland and open habitat in broad zones adjacent to busy roads. The density reduction is related to a reduced habitat quality, and traffic noise is probably the most critical factor. Because density can underestimate the habitat quality, the effects on breeding populations are probably larger than have been established. in consequence, species that did not show an effect on the density might still be affected by traffic noise. On the basis of this recent knowledge, methods have been developed that can be used in spatial planning procedures related to main roads, and in road management practice, and some practical points are discussed. An example of application shows that the effects are probably very important in The Netherlands with a dense network of extremely crowded main roads. For 'meadow birds', which are of international importance, the decrease in population in the West of The Netherlands may amount to 16%. Because breeding birds suffer from many other environmental influences there is also a great risk of an important cumulation of effects.

Reilly, R. E.; Green, H. E. 1974. Deer mortality on a Michigan interstate highway. Journal of Wildlife Management. 38: 16-19.
Collisions increased substantially when an interstate was built through a deer yard, then decreased gradually. Construction of the interstate may be influencing movement patterns. Changes in habitat utilization may be caused by direct mortality of those family groups that originally used the areas. Yearly totals of white-tailed deer killed by automobiles in a northern white cedar deer wintering area

were compiled for a 13 year period from 1960 to 1972. A two-lane highway (formerly U.S. 2) intersects approximately a 5 mile stretch of the wintering area. In 1963, I-75 was constructed roughly parallel to U.S. 2 and about 0.25 miles east of it and thus also intersected the wintering area. In 1964, car-deer kills in the study area increased by approximately 500% over the average of the previous four years. This car-deer kill declined slightly through 1967, and has recently fluctuated about an average which is approximately twice that of the pre-Interstate yearly mortality figure.

Reinhold, J. 1987. Traffic victims. review of methods of road kill study. Amoeba. 987(3): 21-23.

Reolid-Collado, J. M.; Zamora-Salmeron, J. F. 1992. Provisional report of the mortality of vertebrates on the roads of Albacete, September 1991. In: Lopez, Redondo, ed. I jornadas para el estudio y prevencion de la mortalidad de vertebrados en carreteras, Madrid, 5 y 6 de Octubre de 1991. Tomo 2. [Sessions in the study of prevention of road mortalities of vertebrates, Madrid, 5 and 6 October, 1991. Volume 2.]. Ambiental, Madrid: Coordinadora de Organizacciones de Defensa: 118-122.

Repa, P. 1991. Amphibian and reptilian casualties on west Bohemian roads. Zpravy Muzei Zapadoceskeho Kraje. 1: 81-84.

Reudiger, B. 1996. The relationship between rare carnivores and highways. In: Evink, G.; Ziegler, D.; Garrett, P.; Berry, J., eds. Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors: Proceedings of the Florida Department of Transportation/Federal Highway Administration transportation-related wildlife mortality seminar; 1996 April 30-May 2; Orlando, FL. FHWA-PD-96-041. Washington, DC: U.S. Department of Transportation, Federal Highway Administration: 24-38.
The author identified five factors associated with highways that affect carnivores: 1) direct mortality (roadkill, poaching), 2) displacement and avoidance, 3) habitat fragmentation, 4) direct habitat loss, and 5) associated human development.

Rey, W.; Seitz, A. 1990. The influence of land use on the genetic structure of populations of the common frog, *Rana temporaria*. Biological Conservation. 54(3): 239-250.

Rice, Charles R. 1983. A continuation study of the impact of Tennessee State Route 29 upon the avian populations of an adjacent floodplain. Tennessee Technical Journal. 18: 65-71.

Rich, A. C.; Dobkin, D. S.; Niles, L. J. 1994. Defining forest fragmentation by corridor width - the influence of narrow forest-dividing corridors on forest-nesting birds in southern New Jersey. Conservation Biology. 8(4): 1109-1121.
In studies of forest fragmentation, a fundamental inconsistency exists in the distance criterion used to define the discreteness of forest fragments. We examined three types of ubiquitous narrow forest-dividing corridors for effects that influence the relative abundance and community composition of forest-nesting birds. Fixed-radius (100-meter) point counts were conducted on 54 transects established along three width classes of corridors: unpaved roads (8 meters wide), paved roads (IG meters wide), and powerlines (23 meters wide). Transect locations were distributed equally among corridor edge, forest margin 100 meters from corridor edge, and forest interior 300 meters from corridor edge. Forest-interior species of Neotropical migrants had significantly reduced relative abundances on edge transects along 16- and 23-meter corridors, compared with 8-meter corridors and with forest interior points along all three corridor-width classes. At a landscape scale, the consequences of apparently small reductions in forest area by the presence of narrow forest-dividing corridors may be cumulatively significant for abundances of forest-interior species. Brown-headed Cowbirds were more abundant than 20 of 21 forest-interior Neotropical migrants. We found surprisingly high abundances of cowbirds associated with narrow forest-dividing corridors especially those with mowed grass Corridor widths as narrow as 8 meters produce forest fragmentation effects in part by attracting cowbirds and nest predators to corridors and adjacent forest interiors. The most serious implication of this study is that narrow forest-dividing corridors may function as ecological traps for forest-interior neotropical

migrants. We suggest that these widespread corridors may be inconspicuous but important contributors to declines of forest-interior nesting species in eastern North America.

Richardson, J. H.; Shore, R. F.; Treweek, J. R.; Larkin, S. B. C. 1997. Are major roads a barrier to small mammals? Journal of Zoology. 243: 840-846.
Most previous studies are consistent in suggesting that roads restrict the movements of small mammals but are not complete barriers. However, the majority of these studies have examined the impacts of either narrow roads or roads with low traffic density. The present study had two aims. The first was to determine whether major roads (approximately 20 m wide) act as barriers to small mammals. The second aim was to assess whether traffic intensity, rather than simply road width, affected the rate at which small mammals crossed roads. Translocated voles crossed a major highway at a substantially lower rate (33% of translocated individuals) than they crossed a test strip of similar width without traffic (66% of translocated individuals). Roads are permeable barriers to small mammal movement. Roads with higher traffic volumes are less permeable.

Richens, V. B.; Lavigne, G. R. 1978. Response of white-tailed deer to snowmobiles and snowmobile trails in Maine. Canadian Field Naturalist. 92(4): 334-344.

Riffell, S. K. 1997. Road mortality of dragonflies in a freshwater coastal wetland: an example of uncoupled landscape elements. [Abstract]. East Lansing: Michigan State University
Although road mortality of vertebrates has been well-studied, road mortality of invertebrates has rarely been studied or considered in management scenarios. Mackinac Bay is an extensive coastal wetland in northern Michigan which is bisected by a two-lane road, uncoupling the marsh, where dragonflies defend territories and breed, from the adjacent forest where dragonflies forage and rest. During mid-summer of 1997, daily collections of dragonfly casualties from the road verge were used to estimate mortality rates and sex-ratios among casualties. Daily mortality was highly variable, ranging from 4 to 138 casualties per day. Sex-ratios among casualties were generally male-skewed (60% or higher); but were even or female-skewed for some species. Life-history differences between the sexes present a parsimonious explanation for male-specific mortality. Males typically spend most of their adult lives defending potential breeding sites while females spend larger percentage of adult life away from wetland habitats. Reasons for female-specific mortality are not clear, but impacts of roads may be most severe in populations of these species. More research about the effects of roads on dragonflies is warranted because dragonfly populations are small relative to many invertebrates and are restricted to wetland habitats which are being degraded or destroyed in many regions.

Riswan, S.; Hartanti, L. 1995. Human impacts on tropical forest dynamics. Vegetatio. 121(1-2): 41-52.
People living near or in tropical forest ecosystems have traditionally extracted forest products, i.e. timber, food and medicinal plants for their livelihood. Such practice does not create too much disturbance when the population is still sparse, and the product is used only for their own needs. When population pressure becomes greater, and when the motive of extraction is profit, then the disturbance become serious and creates environmental problems. Major exploitation of the Indonesian rain forest for timber began in the 1960s and is continuing today. The lowland rain forests of Sumatra and Kalimantan have been particularly logged. Exploitation has often been destructive because Forest Department rules have been widely ignored. Moreover, once roads have given access to formerly inaccessible areas, farmers have often moved in after the timber companies and then cleared the relict, regenerating forest for either permanent or shifting cultivation. The traditional shifting cultivations have been practiced for years, producing millions of ha of impoverished secondary types of forest, degraded lands and alang-alang (*Imperata cylindrica*) grasslands. Forests have also been lost through conversion of land to plantation agriculture and transmigration programmes, mining, construction roads and railways and also natural disturbances, such as drought and fire. This paper will discuss the human impact upon tropical forest dynamics in general, with examples from Indonesian and other Southeast Asia countries' tropical forests.

Roberts, B. C. 1995. Best management practices for erosion and sediment control. Washington, DC: U.S. Department of Transportation, Federal Highway Administration; FHWA-FLP-94-005. 187 p.

Robinson, S. K.; Wilcove, D. S. 1994. Forest fragmentation in the temperate zone and its effects on migratory songbirds. Bird Conservation International. 4(2-3): 233-249.
Although much attention has been paid to the impacts of tropical deforestation on populations of neotropical migrants, fragmentation of breeding habitat may be an equally serious problem for many of these birds. Populations of many migrant songbirds have been declining in recent decades, especially within small woodlots. Censuses from woodlots of different sizes also consistently show that many migrant songbirds are area-sensitive, i.e. they are absent from all but the largest, woodlots in a region. In contrast, long-term censuses from large, unfragmented forests show few consistent patterns of decline in neotropical migrants. Population declines are therefore linked to forest fragmentation because they are most pronounced in small, isolated woodlots. Fragmentation leads to significant increases in nest predation and cowbird (*Molothrus* spp.) parasitism, the two most important causes of population declines and area-sensitivity. Predation and nest-parasitism rates are higher in small woodlots and along the edges of larger tracts than in the interior of large tracts. Data from fragmented forests in the American Midwest show that reproductive rates of several forest species are probably well below levels necessary to compensate for adult mortality. Among wood thrushes (*Hylocichla mustelina*) nesting in central and southern Illinois, for example, 89-100% of nests contain cowbird eggs (average of 2.2-4.6 cowbird eggs/nest) and nest-predation rates range from 50 to 96%. For the wood thrush and other forest songbirds, fragmented landscapes may be population sinks with populations sustained by immigration from larger, unfragmented forest tracts. These data emphasize the importance of protecting large, unfragmented forests for breeding habitat. We need far better data on dispersal rates and distances, fecundity and survival rates before we can determine what levels of predation and parasitism migratory birds can tolerate. The effects of silvicultural practices such as clear-cutting and selective logging on migratory songbirds may depend upon the landscape context. Preliminary evidence from a fragmented national forest in the Midwest suggests that selective logging can have relatively little impact on forest songbirds. We tentatively propose that low-volume selective logging be used as an alternative to clear-cutting. Logging roads should be closed and revegetated soon after harvest, and rotation times should be lengthened to permit regeneration of large, old trees.

Roblee, K. J. 1987. The use of the t-culvert guard to protect road culverts from plugging damage by beavers. Proceedings of the Eastern Wildlife Damage Control Conference. 3: 25-33.

Rocke, T. E. 1995. Quarterly wildlife mortality report. Journal of Wildlife Diseases. Vol. 31

Rodriguez, A.; Crema, G.; Delibes, M. 1996. Use of non-wildlife passages across a high speed railway by terrestrial vertebrates. Journal of Applied Ecology. 33(6): 1527-1540.
Seventeen culverts and pathway passages across a high speed railway were monitored for one year in order to determine factors influencing their use by terrestrial vertebrates. Carnivores, lagomorphs, small mammals and reptiles used the passages. Crossing rates generally reflected the spatiotemporal variation in vertebrate abundance and activity, suggesting that the passages could be valuable in allowing movement across the railway. Wild ungulates known to be present did not use the passages, probably due to a combination of unsuitable dimensions and placement, a lack of cover near their entrances and human disturbance. Ungulates probably need specifically designed passages. The presence of cover in the passage entrances favoured their use by carnivores, while small mammals preferred narrow passages where, presumably, predation risk was lower. Reptiles preferred passages of intermediate size, in which they moved between sun-warmed and shaded vertical surfaces for thermoregulation. The main factor determining the use of passages by vertebrates was their location with respect to habitat. Minor modifications to non-wildlife passages and to the management of surrounding areas may further improve the efficacy of these passages for allowing wildlife to cross linear barriers and, therefore, potentially reduce the effects of habitat fragmentation.

Rodriguez, A.; Crema, G.; Delibes, M. 1997. Factors affecting crossing of red foxes and wildcats through non-wildlife passages across a high-speed railway. Ecography. 20(3): 287-294.
We used trail records on sand surface within non-wildlife passages to test whether foxes and wildcats used them regularly, and to identify passage features which may favour crossing across a railway and, therefore, may alleviate possible barrier effects. Both species crossed more in places and periods corresponding with assumed peaks in abundance and mobility, thus supporting the regular use hypothesis. The vicinity of cover favoured crossing, but both species used infrequently passages near permanent sources of human perturbation (especially intense traffic) even in suitable habitats with abundant cover. The presence of cover in the passage entrances further favoured fox and wildcat crossing. Cover near entrances may be particularly important to improve carnivore crossing chances in open habitats and when human activity levels are high. Passage design and dimensions had little effect on crossing rates. Location of passages within or close to suitable habitats explained a greater amount of variance in crossing rates than favourable passage features. There was a remarkable similarity in the behaviour of foxes and wildcats, possibly representing the rule for other carnivore species.

Rodriguez, Rojas A. 1992. Provisional report of the mortality of vertebrates on the roads of Cordoba, September 1991. In: Lopez, Redondo, ed. I jornadas para el estudio y prevencion de la mortalidad de vertebrados en carreteras, Madrid, 5 y 6 de Octubre de 1991. Tomo 2. [Sessions in the study of prevention of road mortalities of vertebrates, Madrid, 5 and 6 October, 1991. Volume 2.]. Ambiental, Madrid: Coordinadora de Organizacciones de Defensa: 72-78.

Rolley, Robert E.; Larry, E. L. 1992. Relationships among raccoon road-kill surveys, harvests, and traffic. Wildlife Society Bulletin. 20(3): 313-318.

Romin, L. A.; Dalton, L. B. 1992. Lack of response by mule deer to wildlife warning whistles. Wildlife Society Bulletin. 20: 382-384.
The authors did not detect any differences in responses from 150 groups of free-roaming mule deer to a vehicle mounted with and without wildlife warning whistles. Although these deer were accustomed to vehicular traffic, some had been involved in possessions with vehicles. Had the wildlife warning whistles affected their behavior, differences in responses to a vehicle with or without whistles should have been observed.

Romin, L. A.; Bissonette, J. A. 1996. Deer-vehicle collisions: status of state monitoring activities and mitigation efforts. Wildlife Society Bulletin. 24: 276-283.
We distributed questionnaires to 50 state natural resource agencies in October 1992 to request estimates of deer killed annually on highways, the source of the estimates, and information about methods used to reduce vehicle collisions with deer; 43 agencies responded. Statistics on deer killed by vehicles were highly variable among agencies and were inconsistent among agencies. Despite a limited quantitative basis, the national deer road-kill for 1991 conservatively totaled at least 500,000 deer. Deer road-kills had increased during 1982 to 1991 in 26 of 29 states that had suitable trend data. Nearly all states had used some type of signs, modified speed limits, fencing, over- and underpasses, reflective apparatus, habitat alteration, or public awareness programs, but few agencies had evaluated performance of those techniques. Approaches that alter deer behavior and movement patterns appear to be the most fruitful for future application and evaluation.

Romin, L. A.; Bissonette, J. A. 1996. Temporal and spatial distribution of highway mortality of mule deer on newly constructed roads at Jordanelle Reservoir, Utah. Great Basin Naturalist. 56(1): 1-11.
In this paper we evaluated traffic characteristics and vegetative and topographic features associated with mule deer kills on three highways (U.S. 40, S.R. 32, S.R. 248) in northeastern Utah. We also compared number, and sex and age composition of roadkills to that of the living population observed during spotlight counts. From 15 October 1991 to 14 October 1993 we documented 397 deer roadkills: 51.6% were does, 18.9% bucks, 21.7% fawns, and 7.8% could not be classified. Sixty-seven percent of adult kills were less than or equal to 2.5 years of age. Kill composition compared closely to spotlight counts. Of 1,515 spotlighted deer, 65.2% were does, 8.9% bucks, and 25.9% fawns. Spotlight density and

deer mortality were strongly correlated from summer 1992 through summer 1993 (r = 0.94). Traffic conditions, topographic features, and vegetative characteristics contributed to mortality levels. Roadkills were highest along U.S. 40 (68% year 1, 35% year 2) where traffic volume and speed were significantly higher than along either state route. Large drainages intersected highways in 78% of designated kill zones, Roads adjacent to agricultural areas along all routes sustained the fewest highway mortalities. Percent cover was higher (40%) in kill zones than in other areas (29%).

Roof, J.; Wooding, J. 1996. Evaluation of the S.R. 46 wildlife crossing in Lake County, Florida. In: Evink, G.; Ziegler, D.; Garrett, P.; Berry, J., eds. Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors: Proceedings of the Florida Department of Transportation/Federal Highway Administration transportation-related wildlife mortality seminar; 1996 April 30-May 2; Orlando, FL. FHWA-PD-96-041. Washington, DC: U.S. Department of Transportation, Federal Highway Administration: 329-336.
The study evaluated an experimental wildlife crossing built on S.R. 46 in Lake County, Florida. The wildlife crossing and adjacent barrier fencing were designed primarily to allow black bears to safely cross the highway. Five bears used the wildlife crossing following its completion in December, 1994. Bears encountered the fence or wildlife crossing a total of 50 times. No bears went over or under the fence, but two walked around the ends where they then crossed the highway. At least eleven other species have used the wildlife crossing to make 278 highway crossings. Most crossings were made by rabbits, raccoons, armadillos, opossums, and gray foxes. There were 1,033 documented instances in which animals encountered the barrier fencing and/or wildlife crossing. Most animals (69%) encountering the fence or wildlife crossing did not cross the highway, 27% crossed through the wildlife crossing, and 4% crossed the highway by crawling under the fence or by walking around the ends. The fence and crossing designs were effective as a wildlife crossing for a two-lane highway such as S.R. 46. Life history information collected on bears during the study is reported.

Rose, R. K.; Spevak, A. M. 1978. Interstate roadsides as dispersal routes for *Microtus pennsylvanicus*. Journal of Mammalogy. 59: 208-216.

Rosell, C.; Parpal, J.; Campeny, R.; Jove, S.; Pasquina, A.; Velasco, J. M. 1995. Mitigation of barrier effect of linear infrastructures on wildlife. Proceedings of habitat fragmentation and infrastructure; 1995 September 17-21; Maastricht, The Netherlands.

Rosen, P. C.; Lowe, C. H. 1994. Highway mortality of snakes in the Sonoran Desert of southern Arizona. Biological Conservation. 68(2): 143-148.
We present an algebraic method for estimating highway mortality in snakes, based on careful data collection during low-speed driving on paved roads. A total of 368 snakes (104 live, 264 dead) were recorded over 4 years on State Route 85 from Why to Lukeville, Pima County, Arizona, during 15,525 kilometers of road-cruising; mostly within Organ Pipe Cactus National Monument. We computed an estimate of 2,383 snakes killed (13.5/km/year) during the 4 years on this stretch of pavement, but estimate that actual numbers killed would be closer to 4,000 (22.5/km/year). Two taxa of special conservation interest, the Mexican rosy boa (*Lichanura trivirgata*) and the Organ PiPe shovelnosed snake (*Chionactis palarostris*), appear to be relatively strongly impacted by highway mortality. It is clear that roadways, especially if paved, substantially damage snake populations.

Rost, G. R.; Bailey, J. A. 1979. Distribution of mule deer and elk in relation to roads. Journal of Wildlife Management. 43(3): 634-641.
Responses of deer and elk to roads were assessed by counting fecal-pellet groups near roads on winter ranges. Data were obtained in Colorado in shrub and pine habitats adjacent to paved, gravel, and dirt roads east of the Continental Divide; and in shrub and juniper woodland habitats west of the divide. Deer and elk avoid roads, particularly areas within 200 meters of a road. Road avoidance was greater (1) east of the Continental Divide, (2) along more heavily traveled roads, (3) by deer, compared to elk, and (4) for deer in shrub habitats when compared to pine and juniper habitats. Because of less snow accumulation, winter habitat is more available to cervids east of the continental divide where more

pronounced avoidance of roads presumably results from a greater availability of habitat away from roads.

Ruby, D. E.; Spotila, J. R.; Martin, S. K.; Kemp, S. J. 1994. Behavioral responses to barriers by desert tortoises: implications for wildlife management. Herpetological Monographs.: 144-160.
We conducted tests on the behavioral responses of captive desert tortoises (*Gopherus agassizii*) to barriers and highway obstacles. Desert tortoises are slow-moving but persistent wanderers in their natural habitat. Consequently, they move substantial distances when they meet a barrier that they cannot go around. Tortoises responded differently to solid and non-solid barriers when placed in small pens constructed of various materials. Our tests indicated that a screen mesh with small enough openings to exclude a tortoise's head was the most suitable barrier material. When tortoises were tested for 2-hour periods or after an overnight stay in a barrier pen, rates of responses with barriers declined with time but tortoises continued movement along the barrier. In a choice situation, we found no preference by tortoises for following either solid or mesh barrier fences. Tortoises quickly walked past openings in a barrier which were too small to enter but easily escaped from a barrier pen within 30 minutes when openings of an appropriate size were available. We found tortoises willingly entered culverts under large highways and retreated from concrete highways barriers.

Rudel, Thomas K. 1983. Roads, speculators, and colonization in the Ecuadorian Amazon. Hum. Ecol. 11(4): 385-403.

Rudolph, D. C.; Burgdorf, S. J. 1997. Timber rattlesnakes and Louisiana pine snakes of the West Gulf Coastal Plain: hypotheses of decline. Texas Journal of Science. 49(3): 111-122.
Timber rattlesnakes (*Crotalus horridus*) and Louisiana pine snakes (*Pituophis melanoleucus ruthveni*) are large-bodied snakes occurring on the West Gulf Coastal Plain. Both species are thought to be declining due to increasing habitat alteration. Timber rattlesnakes occur in closed canopy hardwood and pine-hardwood forests, and Louisiana pine snakes in pine forests on sandy, well drained soils. While various factors are probably involved in population declines, this study examined one factor for each species that may have widespread consequences for population viability. Results obtained in this study support the premise that timber rattlesnakes are vulnerable to mortality associated with roads and vehicular traffic. Data and discussion are presented suggesting that populations are negatively impacted in areas of eastern Texas having a high road density. Conversely, Louisiana pine snakes appear to be affected by changes in the fire regime which has altered vegetation structure resulting in decreases in pocket gopher (*Geomys breviceps*) density. Decreases in gopher densities are further hypothesized to result in decrease or extirpation of pine snake populations.

Rudolph, D. C.; Burgdorf, S. J.; Conner, R. N.; Dickson, J. G. 1998. The impact of roads on the timber rattlesnake (*Crotalus horridus*), in eastern Texas. In: Evink, G. L.; Garrett, P.; Zeigler, D.; Berry, J., eds. Proceedings of the international conference on wildlife ecology and transportation; 1998 February 10-12; Ft. Myers, FL. Tallahassee, FL: Florida Department of Transportation: 236-240.
Roads and associated vehicular traffic have the potential to significantly impact vertebrate populations. In eastern Texas we compared the densities of paved and unpaved roads within 2 and 4 kilometer radii of timber rattlesnake (*Crotalus horridus*) locations and of random points. Road networks were significantly more dense at random points that at snake localities. A similar relation was detected within permanent stream corridors where extant populations of rattlesnakes are concentrated. Our data suggest that roads and associated vehicular traffic have had a detrimental impact on the current distribution of *C. horridus* in eastern Texas.

Ruediger, B. 1998. Rare carnivores and highways - moving into the 21st century. In: Evink, G. L.; Garrett, P.; Zeigler, D.; Berry, J., eds. Proceedings of the international conference on wildlife ecology and transportation; 1998 February 10-12; Ft. Myers, FL. Tallahassee, FL: Florida Department of Transportation: 10-16.
A serious conservation issue is facing rare carnivores (grizzly bear, *Ursus arctos*; gray wolf, *Canis lupus*; wolverine, *Gulo gulo*; lynx, *Lynx canadensis*; fisher, *Martes pennanti*) is the impacts created by highways.

Carnivores are vulnerable to highways because of their large spatial requirements, which require frequent crossings of busy roads. Several carnivores also have low reproductive productivity, which can contribute to their extirpation. Highways are habitat and ecosystem issues. Highways affect carnivores by creating serious habitat fragmentation, increasing direct and indirect mortality, habitat loss, displacement and avoidance, and accelerating associated human developments. The impacts of highways on carnivores are permanent and severe. Rare carnivores face serious threat or eventual extirpation in the lower 48 states and southern Canada if highway issues are not addressed and solved. Presently, little or no emphasis is placed on highway impacts by land management agencies, wildlife agencies, conservation organizations or highway agencies. Suggested priorities for reducing highway impacts on carnivores include 1) development and implementation of national policies requiring the Federal Highways Administration and land management agencies to address highway impacts on wildlife species-particularly rare carnivores, 2) better highway planning and coordination standards, 3) identification and management of critical land corridors, 4) implementation of highway crossing structures for wildlife, and 5) emphasis on highway research.

Ruefenacht, B.; Knight, R. L. 1995. Influences of corridor continuity and width on survival and movement of deermice (P*eromyscus maniculatus*). Biological Conservation. 71(3): 269-274.
We investigated the effects of corridor gaps and corridor width on the survival and movement of resident and non-resident deermice (*Peromyscus maniculatus*). Transplanted non-resident deermice were used to simulate dispersing individuals, and resident deermice served as controls. The study design was a completely randomized 2(2) factorial with width (narrow or wide) and continuity (with or without a 10-meter-wide corridor gap) as factors of interest. Vegetation variables were more significant with movement and number of crossings than were width and continuity. Survival was unaffected by corridor width and continuity, as well as vegetation variables.

Russell, C. F. 1978. A movement barrier useful in population studies of small mammals. American Midland Naturalist. 100: 400-402.

Russell, H. N. 1938. A notes on highway mortality. Wilson Bulletin. 50: 205-206.

Rutter, A. J.; Thompson, J. R. 1986. The salinity of motorway soils. III. Simulation of the effects of salt usage and rainfall on sodium and chloride concentrations in the soil of central reserves. Journal of Applied Ecology. 23: 281-297.

Rydell, J. 1992. Exploitation of insects around streetlamps by bats in Sweden. Fundamental and Applied Nematology. 6(6): 744-750.
Nine species of insectivorous bats in southern Sweden were monitored with a bat detector to assess which species regularly forage around streetlamps and which do not. Only the fast-flying species that use long-range echolocation systems (*Nyctalus noctula, Vespertilio murinus, Eptesicus nilssonii* and occasionally *Pipistrellus pipistrellus*) did, whereas *Myotis* spp. and *Plecotus auritus* did not. Bats foraging near street lamps were monitored with a bat detector from a car. Bat density along illuminated roads was 1-5/km. More than 90% of the bats detected were *E. nilssonii.* In and around a small town, *E. nilssonii* was predominantly found in residential and rural parts, and avoided areas without trees. *Vespertilio murinus*, in contrast, was observed in all habitats. The difference was probably related to differences in the foraging behaviour of the two species. The attractiveness to insects by streetlamps was determined photographically. The various lamp types attracted insects in relation to the amount of short wave-lengths emitted. Bats were attracted to the same lamp types as insects. The gross energy intake of *E. nilssonii* foraging around streetlamps was more than twice as high (0.5 kJ/min) as previously recorded in woodlands (0-2 kJ/min) but slightly lower than over pastures where dung beetles occurred (0.6 kJ/min). The results have implications for the conservation of bats. Generally, the fast-flying species will probably be least likely to suffer from a general decline in insect abundance. Priorities should therefore be given to the needs of the slow-flying bat species.

Rydell, J.; Baagoe, H. J. 1996. Street lamps increase bat predation on moths. Entomologisk Tidskrift. 117: 129-135.
Streets and roads lit by mercury vapour streetlamps provide important feeding habitats for several species of bats, because the lights attract insects, including moths, which thus become easily accessible to the predators. Some common Scandinavian bat species, mostly the northern bat (*Eptesicus nilssonii*), the particoloured bat (*Vespertilio murinus*) and the serotine (*Eptesicus serotinus*), occur at high densities near streetlights (usually two to five bats per km, occasionally up to 20 per km). Bats foraging around streetlights catch male moths in large numbers. The effect of the increased predation on the moth populations is unknown. Mercury vapour lights are currently replaced by environmentally more friendly orange sodium lights in many areas. Sodium lamps do not attract insects to the same extent. The replacement will therefore result in decreased food availability for bats that forage near lights (such as those mentioned above). Our threatened bat species seldom feed near streetlights, and will therefore not be affected directly by the replacement.

Ryser, J.; Grossenbacher, K. 1989. A survey of amphibian preservation at roads in Switzerland. In: Langton, T. E. S., ed. Amphibians and roads. Proceedings of the toad tunnel conference; 1989 January 7-8; Rendsburg, Federal Republic of Germany. Shefford, England.: ACO Polymer Products Ltd.: 7-13.

Sage, R. W.; Tierson, W. G.; Mattfeld, G. F.; Behrend, D. F. 1983. White-tailed deer visibility and behavior along forest roads. Journal of Wildlife Management. 47: 940-962.

Sainsbury, A. W.; Bennett, P. M.; Kirkwood, J. K. 1995. The welfare of free-living wild animals in Europe: harm caused by human activities. Animal Welfare. 4: 183-206.
As part of a study into the effects of human activities on the welfare of free-living wildlife, the relative scale and severity of welfare problems in wild mammals and birds in Europe were investigated. Major cases were described and compared in terms of the nature and level of harm (pain, stress and fear) they cause, the duration of these effects and the number of individuals affected. The use of anticoagulant rodenticides, myxomatosis in rabbits, the poisoning of wildfowl by ingested lead shot, the contamination of seabirds with fuel oil, the effects of shooting, injuries due to collisions with road traffic and predation by domestic cats all severely compromise the welfare of large numbers of animals. Practical approaches to the alleviation and prevention of some of these welfare problems are discussed. We suggest that in assessing the environmental impact of new developments and technologies prior to their implementation, possible consequences to wildlife welfare should always be considered.

Salwasser, Hal; Douglas, J. T.; Young, D. L. 1980. The use of road-killed deer for assessing reproductive potential and winter condition of the Devil's Garden Interstate mule deer herd. California Fish and Game. 66(2): 105-111.

Sanchez-Clemot, J. F. 1992. Provisional report of the mortality of vertebrates on the roads of the north western parts of Granada Province, September 1991. In: Lopez, Redondo, ed. I jornadas para el estudio y prevencion de la mortalidad de vertebrados en carreteras, Madrid, 5 y 6 de Octubre de 1991. Tomo 2. [Sessions in the study of prevention of road mortalities of vertebrates, Madrid, 5 and 6 October, 1991. Volume 2.]. Ambiental, Madrid: Coordinadora de Organizacciones de Defensa: 79-87.

Sanderson, K. 1983. Wildlife roadkills and potential mitigation in Alberta. Edmonton, Alberta: Environmental Council of Alberta.; ECA83-ST/1. [Pages unknown].
The author reviewed ungulate roadkill rates and potential effects on populations and suggest that there are none. He also briefly reviewed mitigation techniques.

Sandilands, A. 1994. Research program on wetland assessment and the effects of highways on wildlife. Ottawa, Ontario: Research and Development Branch, Ontario Ministry of Transportation. [Pages unknown].

Sargeant, A. B. 1981. Road casualties of prairie nesting ducks. Wildlife Society Bulletin. 9: 65-69.

Sargeant, Alan B.; James, E. F. 1973. Mortality among birds, mammals and certain snakes on 17 miles of Minnesota roads. Loon. 45(1): 4-7.

Sargent, Robert R.; Sargent, Martha B. 1996. Great crested flycatcher (*Myiarchus crinitus*) feeding at road kills. Alabama Birdlife. 42(2): 10-12.
The authors observed great crested flycatchers feeding at road kill on highways in Alabama. The birds were taking Diptera larva from the carcass to their nest in the nearby woods. This foraging behavior appears to be more energy efficient than catching prey in the air.

Saunders, D. A.; Hobbs, R. J.; Margules, C. R. 1991. Biological consequences of ecosystem fragmentation: a review. Conservation Biology. 5: 18-32.

Savidge, T.; Bain, H. 1996. Protected species impacts and habitat management associated with transportation projects in North Carolina. In: Evink, G.; Ziegler, D.; Garrett, P.; Berry, J., eds. Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors: Proceedings of the Florida Department of Transportation/Federal Highway Administration transportation-related wildlife mortality seminar; 1996 April 30-May 2; Orlando, FL. FHWA-PD-96-041. Washington, DC: U.S. Department of Transportation, Federal Highway Administration: 141-152.
The authors present an overview of the North Carolina Department of Transportation's NEPA program, and briefly discuss case studies involving bald eagle, red-cockaded woodpecker, freshwater mussels, and fish.

Savidge, T. 1998. Management of protected freshwater mussels with regard to North Carolina Department of Transportation highway projects. In: Evink, G. L.; Garrett, P.; Zeigler, D.; Berry, J., eds. Proceedings of the international conference on wildlife ecology and transportation; 1998 February 10-12; Ft. Myers, FL. Tallahassee, FL: Florida Department of Transportation: 143-150.
No other faunal group in North America is as critically imperiled as the freshwater mussels. Five federally protected mussel species occur in North Carolina. These mussels have accounted for 35% of the Section 7 consultations that the North Carolina Department of Transportation (NCDOT) has been involved with. The NCDOT has developed a management strategy to ensure that concerns with protected mussels are resolved early in the planning process, so that project schedules are met and the mussel resource is not compromised. Protective and conservation measures that were taken on four NCDOT projects that involved protected mussels are highlighted.

Saxena, R. 1992. Mortality rate in common Indian nightjar in road accidents. Newsletter For Birdwatchers. 2(9-10): 17-22.

Scanlon, Patrick F.; Susan, M. M. 1980. Approaches by states to educating drivers about wildlife hazards on roads. Proceedings of the Annual Conference of the Southeast Association of Fish and Wildlife Agencies. 33: 765-766.

Schafer, J. A.; Penland, S. T. 1985. Effectiveness of Swareflex reflectors in reducing deer-vehicle accidents. Journal of Wildlife Management. 46: 774-776.
Most studies of headlight reflectors for deer are confounded by spatial differences in deer distributions or changes in deer population size, traffic patterns, and weather. This study used alternately covered and uncovered reflectors to allow comparison of the presence and absence of headlight reflections under otherwise comparable conditions. In the test sections of highway in Washington, 56 white-tailed deer (*Odocoileus virginianus*) and two mule deer (*O. hemionus*) were killed at night. Of these, 52 were killed when reflectors were covered and six were killed when reflectors were uncovered, a significant difference ($P<0.005$).

Schafer, J. A.; Penland, S.; Carr, W. P. 1985. Effectiveness of wildlife warning reflectors in reducing deer-vehicle accidents in Washington State. Transportation Research Record.: 85-88.
The effectiveness of Swareflex wildlife reflectors in reducing deer-vehicle collision rates was tested on

S.R. 395 in eastern Washington State, on which high mortality rates of white-tailed deer (*Odocoileus virginianus*) had previously been recorded. Reflectors were placed in four test sections and alternately covered and uncovered at regular intervals during the late fall to early spring period from 1981 to 1984. During this period 52 deer were killed at night in test sections when the reflectors were covered and six deer were killed at night when the reflectors were uncovered.

Schippers, P.; Verboom, J.; Knaapen, J. P.; Vanapeldoorn, R. C. 1996. Dispersal and habitat connectivity in complex heterogeneous landscapes - an analysis with a GIS-based random walk model. Ecography. 19(2): 97-106.
A grid-based random walk model has been developed to simulate animal dispersal, taking landscape heterogeneity and linear barriers such as roads and rivers into account. The model can be used to estimate connectivity, and has been parameterized for the badger in the central Netherlands. The importance of key parameters was evaluated by means of sensitivity analysis. Results agree with field observations, and give interesting insight into the isolation of populations and potential populations. The model can be applied to obtain knowledge about dispersal processes in complex landscapes.

Schlupp, I.; Kietz, M.; Podloucky, R.; Stolz, F. M. 1989. Pilot project Braken: preliminary results from the resettlement of adult toads to a substitute breeding site. In: Langton, T. E. S., ed. Amphibians and roads. Proceedings of the toad tunnel conference; 1989 January 7-8; Rendsburg, Federal Republic of Germany. Shefford, England: ACO Polymer Products Ltd.: 127-135.

Schmidly, D. J.; Wilkins, K. T. 1977. Composition of small mammal populations on highway right-of-ways in east Texas. Washington, DC: U.S. Department of Transportation, Federal Highway Administration; FHWA/TX-77197-IF. [Pages unknown].
Many species of wildlife occur along roads. Most rodents spend their entire lives within the rights-of-ways (ROWs); larger species are transients which feed within ROWs. Mowing affects abundance of rodents. Species preferring denser cover were more plentiful in unmowed ROWs than in mowed ROWs. Species preferring sparse cover were more abundant in mowed ROWs than in unmowed ROWs. Rodent diversity was greater in less-disturbed habitats (old fields). The types of vegetation occurring in an area influence rodent diversity and abundance. Less than one percent of the rodent community living within ROWs died on the highways. Relative impact of highway mortality on populations of larger animals is probably greater than on rodents, but is probably still negligible. Number of fatalities decreased as traffic volume increased.

Schonewald-Cox, C.; Buechner, M. 1992. Park protection and public roads. In: Fiedler, P. J.; Jain, S. K., eds. Conservation biology: the theory and practice of nature conservation, preservation and management. New York: Chapman and Hall: 373-395.

Schorger, A. W. 1984. A study of roadkills. Passenger Pigeon. 16: 53-55.

Schreiber, K. F.; Kias, U. 1983. A concept for environmental impact assessment of new roads. Applied Geography and Development. 21: 95-107.

Schreiber, R. K.; Graves, J. H. 1977. Powerline corridors as possible barriers to the movement of small mammals. American Midland Naturalist. 97(2): 504-508.
The authors did not detect a significant barrier effect for small mammals trapped within a powerline right-of-way with well-developed ground cover.

Schulz, T. T.; Joyce, L. A. 1992. A spatial application of a marten habitat model. Wildlife Society Bulletin. 20: 74-83.
The implications of a spatial application of a marten habitat model and changing grain size were investigated by assessing the amount of habitat within potential home ranges. Spatially explicit applications predicted fewer suitable home ranges than spatially neutral applications. As grain size increased, the predicted number of suitable home ranges did not vary until grain size was > 1% home

range size. The size and spatial distribution of habitat patches, as well as the total amount of habitat, influenced the degree to which changing grain size modified wildlife habitat estimations. Models need to incorporate spatial aspects of habitat for species that recognize juxtaposition as well as amount of habitat. In this study, juxtaposition was examined by assessing the amount of habitat within a potential home range. Other aspects of juxtaposition such as distance to water or road density may be important to other species and should be examined. For example, mule deer (*Odocoileus hemionus*) and elk (*Cervus elaphus*) do not use available forage in the middle of large meadows (Reynolds 1966), and grizzly bears (*Ursus arctos*) forage less than expected in areas within 100 m of roads (McLellan and Shackleton 1988). In addition, species with specific habitat requirements may be difficult to model with a GIS that contains generalized vegetation characters (Donovan et al. 1987). This study indicated that species that respond to changes in habitat occurring below the grain of available data will not be accurately modelled. The Forest Service is responsible for providing habitat for all indigenous and selected exotic species that utilize the landscape at a wide range of spatial scales. A grain size of 30 times 30 m is more than adequate for a marten but is only 25% of a Southern redbacked vole's (*Clethrionomys gapperi*) home range (Hoover and Wills 1984: 75-198). The choice of grain size must be sensitive to special habitat requirements and intended model use as well as home range size. As grain size is increased, small, rare patches of habitat or linear features such as streams and roads may not be discernible. When using wildlife habitat models within a GIS, the grain must be appropriate to the species of concern.

Schwartz, O. A.; Vivas, A. M.; Orris, A.; Miller, C. J. 1994. Small mammal species associations in three types of roadside habitats in Iowa. Prairie Naturalist. 26: 45-52.
We snap-trapped the small mammals in native prairie, reconstructed prairie, and weedy roadsides. The house mouse (*Mus musculus*) was significantly more abundant in the reconstructed prairie roadsides. The species pairs of house mouse/meadow vole (*Microtus pennsylvanicus*), house mouse/deer mouse (*Peromyscus maniculatus*), and meadow vole/deer mouse were positively associated in the reconstructed prairie roadsides, and the meadow vole/deer mouse pair was positively associated in the native prairie roadsides. There was no evidence of interspecific competition. Predation by short-tailed shrews (*Blarina brevicauda*) may affect the distribution of the house mouse, but their negative association is more likely due to preference of the shrew for later and the house mouse for earlier stages of grassland succession. The abundance of meadow voles was greatest in the absence of short-tailed shrews, but this pair was positively associated across habitats. The diversity of habitats created by the seeding and maintenance of reconstructed prairie roadsides and other vegetation disturbances has created niches that promoted species associations.

Scott, T. G. 1938. Wildlife mortality on Iowa highways. American Midland Naturalist. 20: 527-539.

Scribner, K. T.; Smith, M. H.; Chesser, R. K. 1997. Spatial and temporal variability of microgeographic genetic structure in white-tailed deer. Journal of Mammalogy. 78(3): 744-755.
Techniques are described that define contiguous genetic subpopulations of white-tailed deer (*Odocoileus virginianus*) based on the spatial dispersion of 4,749 individuals that possessed discrete character values (alleles or genotypes) during each of 6 years (1974 to 1979). White-tailed deer were not uniformly distributed in space, but exhibited considerable spatial genetic structuring. Significant non-random clusters of individuals were documented during each year based on specific alleles and genotypes at the Sdh locus. Considerable temporal variation was observed in the position and genetic composition of specific clusters, which reflected changes in allele frequency in small geographic areas. The position of clusters did not consistently correspond with traditional management boundaries based on major discontinuities in habitat (swamp versus upland) and hunt compartments that were defined by roads and streams. Spatio-temporal stability of observed genetic contiguous clusters was interpreted relative to method and intensity of harvest, movements, and breeding ecology.

Seabrook, W. A.; Dettmann, E. B. 1996. Roads as activity corridors for cane toads in Australia. Journal of Wildlife Management. 60(2): 363-368.
The toxic cane toad (*Bufo marinus*) has been introduced to Australia. We investigated the distribution of cane toads in relation to roads and tracks in Australia, where this species has the potential to affect

native wildlife. Cane toads were more dense (P = <0.05) on roads and vehicle tracks than in many types of surrounding vegetation. Furthermore, toads used roads as activity and dispersal corridors, especially in forested habitats and other habitats with dense ground and tree canopy vegetation. Roads, therefore, assist toads to extend their range and road construction can facilitate colonization by toads of previously inaccessible areas, which could further degrade fragmented forest.

Selander, R. K.; Kauffman, D. W. 1975. Genetic structure of populations of the brown snail (*Helix aspersa* I.): microgeographic variation. Evolution. 29: 385-401.

Sere, D. 1990. Barn owl - eastern form - cadavers found on roads. Acrocephalus (Ljubljana). 1(46): 111-118.

Serre, D.; Birkan, M. 1985. Impact of insecticides on the food of grey partridge chicks (*Perdix perdix* L.) on arable farmland in the Beauce region. Gibier Faune Sauvage. 985(4): 21-61.

Servheen, C. 1993. Grizzly bear recovery plan. Washington, DC: U.S. Fish and Wildlife Service 204 p.

Servheen, C.; Sandstrom, P. 1993. Ecosystem management and linkage zones for grizzly bears and other large carnivores in the northern Rocky Mountains in Montana and Idaho. Endangered Species Bulletin. 18: 1-23.

Servheen, C.; Sandstrom, P. 1993. Human activities and linkage zones for grizzly bears in the Swan-Clearwater Valleys, Montana. Missoula, MT: U.S. Fish and Wildlife Service. 28 p.

Servheen, C.; Waller, J.; Kasworm, W. and others. 1997. Determining effects of high-speed highways on grizzly bear movement, mortality, habitat-use, and habitat fragmentation-draft proposal. Missoula, MT: U.S. Fish and Wildlife Service. [Pages unknown].

Servheen, C.; Waller, J.; Kasworm, W. 1998. Fragmentation effects of high-speed highways on grizzly bear populations shared between the United States and Canada. In: Evink, G. L.; Garrett, P.; Zeigler, D.; Berry, J., eds. Proceedings of the international conference on wildlife ecology and transportation; 1998 February 10-12; Ft. Myers, FL. Tallahassee, FL: Florida Department of Transportation: 97-103.
Grizzly bears (*Ursus arctos horribilis*) populations in the conterminous United States are grouped into six recovery areas, five of which presently have bears. Four of these five areas are contiguous with Canada. High-speed highways bisect many of these ecosystems including the Northern Continental Divide, Cabinet-Yaak, Selkirk, and North Cascades. These highways are habitat framentation factors. Highway impacts include vehicle collisions and avoidance of vehicle noise by bears, inhibition of movement by loss of vegetation and changes along highways, fencing and other barriers along or between highway lanes, and the human developments that occur along highways. These highways have the potential to fracture grizzly bear populations across the United States-Canada border by inhibiting movements, increasing mortality, and inhibiting genetic and demographic exchange. Maintaining opportunities for demographic and genetic linkage between United States and Canadian grizzly bear populations enhances survival and recovery potential. We propose a three-phase approach to deal with this issue including 1) development of information on how grizzly bears relate to and cross highways and development of a conceptual model to identify sites where highway crossings by grizzly bears would be most likely; 2) development of crossing structures and highway design modifications at such specific sites; and 3) monitoring effects of highways on populations of bears and use of mitigation measures by bears in a long-term effort to assure population connectivity.

Severinghaus, William D.; Mary, C. S. 1982. Effects of tracked vehicle activity on bird populations. Environmental Management. 6(2): 163-169.

Sharma, Satish K. 1988. Bird casualties in road accidents. Journal of the Bombay Natural History Society. 85(1): 195-197.

Sharp, H. S. 1930. Red-headed woodpeckers and automobiles. BirdLore. 32: 352-356.

Shaw, E. A. 1996. Noise environments outdoors and the effects of community noise exposure. Noise Control Engineering Journal. 44(3): 109-119.
Man-made noise, especially transportation noise, creates acoustical environments that are vastly different from those associated with pristine habitats. During the past 25 years, the day-night average sound level, has gained substantial acceptance as a measure of community noise exposure. During the same period, the effects of various levels of noise exposure on human activities and health have been widely studied. Data from many social surveys have been brought together and analyzed to clarify the relationship between noise exposure and the prevalence of annoyance which provides a broad indication of the impact of intrusive noise on human communities. Criteria and guidelines based on such studies are now widely used in urban planning and their effectiveness is enhanced by new standards that characterize sound propagation outdoors. Regulations that control motor vehicle noise at the source have, as yet, produced only limited benefits, while highway barriers provide some relief from excessive exposure to traffic noise. In recent years, there have been impressive reductions in the noise emissions from commercial aircraft and notable improvements in the control of airport noise. Finally, the potential effects of noise on wildlife, especially endangered species, now come under close scrutiny when noise-generating projects are planned in sensitive environments.

Sheate, W. R.; Taylor, R. M. 1990. The effect of motorway development on adjacent woodland. Journal of Environmental Management. 31: 261-267.

Shelton, P. A. 1982. The impacts of Tennessee State Route 29 upon the avian populations of an adjacent floodplain [Abstract]. Tennessee Technical Journal. 17: 81-81.

Sherburne, J. H. 1983. Wildlife populations utilizing right-of-way habitat along Interstate 95 in northern Maine. Washington, D.C.: U.S. Department of Transportation, Federal Highway Administration; FHWA-ME-TP-83-5. [Pages unknown].

Shideler, R. T.; Robus, M. H.; Winters, J. F.; Kuwada, M. 1986. Impacts of human developments and land use on caribou: a literature review. Volume I: a worldwide perspective. Anchorage, AK: Alaska Department of Fish and Game; 86-2. 234 p.
Historical range of the report covers the Soviet Union, Finland, Norway, the Pacific Northwest and Western Canada, as well as Alaska and the New England and Great Lakes states.

Shury, T. K. 1996. A summary of wildlife mortality in Banff National Park 1981-1995, final report. Banff, Alberta: Parks Canada, Banff National Park Warden Service. 29 p.

Siebart, H. C.; Conover, J. H. 1991. Mortality of vertebrates and invertebrates on a Athens County, Ohio highway. Ohio Journal of Science. 91: 163-166.

Silva, J. M. 1991. Turning up the heat on fire ants. Newsletter of the Michigan Entomological Society. 6(1): 8-10.

Silvester, D. 1993. Transit New Zealand and the environment. Road and Transport Research. 2(4): 4-15.
Consideration of the effects of construction and maintenance of New Zealand's land transport system on the environment have long played an important part in planning and managing the system. However, concern over the effects which traffic, roading development and road use have on the environment has continued to grow in recent years. Further, New Zealand's Resource Management Act (1991) promotes the concept of sustainable management of natural and physical resources. Taking account of the community's concerns and the requirement for sustainable management of the land transport system, Transit New Zealand is committed to taking further initiatives to protect the environment. This will be accomplished by reducing the adverse effects the land transport system may have in terms of the landscape, traffic noise, air and water pollution, the destruction of native wildlife habitats, social disruption and historical sites and buildings.

Simberloff, D.; Farr, J. A.; Cox, J.; Mehlman, D. W. 1992. Movement corridors: conservation bargains or poor investments? Conservation Biology. 6(4): 493-504.
They argue that there is a paucity of data showing how corridors are used and whether the use lessens extinction risk. They point out confusion in the use of the term 'corridor'. Examples of high cost corridors in southern Florida are used to back up the argument.

Simmons, J. R. 1938. Feathers and fur on the turnpike. Boston, Massachusetts: Christopher Publishing House. 148 p.

Simpson, K.; Gyug, L. 1991. Effects of the Okanagan connector freeway on wildlife and effectiveness of mitigation techniques. [Location of publisher unknown]: Keystone Wildlife Research for the British Columbia Ministry of Transport and Highways. 41 p.

Singer, F. J. 1978. Behavior of mountain goats in relation to U.S. Highway 2, Glacier National Park, Montana. Journal of Wildlife Management. 42: 591-597.
A study was conducted in 1975 on mountain goads crossing a highway to visit a natural mineral lick. Eighty-seven successful crossings of the highway involving 692 mountain goats were observed, and an estimated 812 crossings occurred during the 1975 lick season. Crossing success was associated ($P<0.05$) with the size of groups, all groups (2 to 55 goats) being more successful than individuals. Crossing success was also associated ($P<0.005$). Collision hazards and high disturbance during crossings suggested that a goat crossing should be constructed and visitors should be restricted from the crossing area.

Singer, F. J.; Beattie, J. B. 1985. The controlled traffic system and associated wildlife responses in Denali National Park. Arctic. 39: 195-203.

Singer, F. J.; Doherty, J. L. 1985. Managing mountain goats at a highway crossing. Wildlife Society Bulletin. 13: 469-477.

Singer, F. J.; Doherty, J. L. 1985. Movements and habitat use in an unhunted population of mountain goats (*Oreamnos americanus*). Canadian Field Naturalist. 99: 205-217.

Singer, F. J.; Langlitz, W. L.; Samuelson, E. C. 1985. Design and construction of highway underpasses used by mountain goats. Transportation Research Record. 1016: 6-10.

Singer, F. J.; Beattie, J. B.; Cunningham, R. C. 1986. Large mammals and roads in national parks--a review. Conference on Science in National Parks. 4: 134-139.

Singleton, P. H. 1995. Winter habitat selection by wolves in the north fork of the Flathead River Basin, Montana and British Columbia. Missoula, MT: University of Montana. 116 p. M.S. thesis.
We found that wolf home ranges were located in areas with less than 4miles per square mile road density significantly greater than expected based on availability and that intra-territorial winter travel routes were in areas with 0.01-2mi/mi^2 road density significantly greater than expected. Roadless areas were least used for intra-territorial travel. Traditional travel routes were located in valley bottoms and lower slopes, which coincided with the location of roads. Lightly used roads were also used for travel.

Sinha, Kumares C.; Kang, Hu; John, D. N. 1984. Current practices of harvesting hay on highway rights-of-way. Transportation Research Record. 969: 40-45.

Skoglund, R. R. 1983. Estimated impact of a state highway on mammal populations, distributions, and home ranges. Tennessee Technical Journal. 18: 68-72.

Skolving, H. 1987. Traffic accidents with moose and roe deer in Sweden. Report of research, development and measures. In: Bernard, J. M.; Dansirat, M.; Kempf, C.; Tille, M., eds. Routes et faune sauvage: actes du colloque. Strasbourg: Conseil de l'Europe: 317-325.

Skoog, P. J. 1982. Highways and endangered wildlife in Florida: impacts and recommendations. Tallahassee, FL: Florida Game and Fresh Water Fish Commission; FHWA/FLBMR/84272; FLE/R2784. 106 p. Sponsored by the Federal Highway Administration and Florida State Department of Transportation, Bureau of Environment.
This report is designed to provide the Florida Department of Transportation with information and recommendations to avoid or mitigate adverse impacts to threatened or endangered species. The species selected for specific discussion have been or potentially will be impacted by highway construction, operation or maintenance procedures, and all recommendations are based on current knowledge of each species' life history, habitat needs and vulnerability to disturbance. Also, included is a listing of endangered and threatened species which could be encountered in each Florida county and that should be considered in land-use planning.

Smallwood, K. S.; Fitzhugh, E. L. 1995. A track count for estimating mountain lion (*Felis concolor californica*) population trend. Biological Conservation. 71(3): 251-259.
Reliable estimates of status and population trend are critical for conservation of large terrestrial carnivores, but are usually lacking due to the high costs of sampling across large geographic areas. For detecting population trends of mountain lion *Felis concolor california*, we evaluated counts of track sets on 48 randomly chosen quadrats in California. Each quadrat contained 33.8 kilometers of transect on dusty, dirt roads, which were chosen by local wildlife biologists. A count of track sets by one person on all quadrats was more efficient than recording presence/absence by local survey teams. We estimated an efficient sample size of 44 quadrats in California after applying our data to a general formula for contagious distributions. This sample size can be reduced substantially by choosing new transect locations based on associations of tracks with topography and habitat. Tracks were most likely found on roads along 1st- and 2nd-order streams, on mountain slopes and knolls/peaks, and in oak woodland and montane hardwood-conifer forest. A changing mountain lion population can be detected with an inexpensive, periodic track survey and self-stratifying, non-parametric tests. Each track survey across California can be finished in 30 days. The many mountain lions and the variety of environmental conditions included at this extraordinarily large spatial scale permit estimates of (1) trends among population strata in quadrats that are clustered according to typical number and age/sex class of track sets; (2) population size and demography after individuals are identified by their tracks, and after linear density on roads is calibrated from spatial density at intensive study sites; and (3) spatio-temporal associations with bobcat *Felis rufus*, black bear *Ursus americanus*, coyote *Canis latrans*, and fox *Vulpes vulpes* and *Urocyon cinereoargenteus.*

Smardon, R. C.; Singer, F. J.; Langlitz, W. L. and others. 1985. Roadside environment. Washington, DC: Transportation Research Board; TRB/TRR-1016. 36 p.
The five papers in the report cover the following areas: a visual approach to redesigning the commercial strip highway; design and construction of highway underpasses used by mountain goats; wildlife use of roadside woody plantings in Indiana; wildlife populations utilizing right-of-way habitat along Interstate 95 in northern Maine; and, exposure and risk assessment, health monitoring, and risk management for herbicide applicators.

Smislovs, V. 1990. Methods of counting birds perished on motor-roads. Putni Daba. 1990: 169-170.

Smith, Alan D.; Schubert, David. 1988. Discriminating degree of white-tailed deer travel route use. Proceedings of the West Virginia Academy of Science. 60(1): 19-20.

Smith, D. J. 1995. The direct and indirect impacts of highways on the vertebrates of Payne's Prairie State Preserve. Gainsville, FL: Department of Wildlife Ecology and Conservation, University of Florida. [Pages unknown].

Smith, D. J.; Harris, L. D.; Mazzotti, F. J. 1996. A landscape approach to examining the impacts of roads on the ecological function associated with wildlife movement and movement corridors: problems and solutions. In: Evink, G.; Ziegler, D.; Garrett, P.; Berry, J., eds. Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors: Proceedings of the Florida Department of Transportation/Federal Highway Administration transportation-related wildlife mortality seminar; 1996 April 30-May 2; Orlando, FL. FHWA-PD-96-041. Washington, DC: U.S. Department of Transportation, Federal Highway Administration: 260-272.
This paper addresses the development of criteria for prioritizing greenway-highway intersections to implement a construction plan for wildlife crossings. The authors describe on-going analysis of linkage zones in Florida, and use of the linkage analysis to determine priorities for establishment of wildlife crossing areas. The modelling will be based upon habitat values determined by factors identified in a survey of experts but has not been completed at this time.

Smith, Douglas L. 1978. Wildlife considerations in rights-of-way management. Rural Urban Roads. 16(2): 26-28.

Smith, W. G. 1981. Observations of a large highway kill of evening grosbearks in British Columbia. Syesis. 14: 163-164.

Smith, W. T.; Cameron, R. D.; Reed, D. J. 1994. Distribution and movements of caribou in relation to roads and pipelines, Kuparuk development area, 1978-90. Alaska Department of Fish and Game, Division of Wildlife Conservation Wildlife Technical Bulletin. 2: 1-54.

Solheim, R.; Engan, J. H.; Engan, H. J. 1995. A corridor into the future for wild reindeer (*Rangifer tarandus*) in Norway. Fauna. 48: 90-95.
Wild reindeer is a highly nomadic species, migrating from winter- to summer-grazing grounds. Many important migration routes have been destroyed by technical installations such as railways, roads and hydroelectric power dams and lines, thus splitting reindeer into small populations, each population often left with insufficient grazing resources. We propose that such damage could be reversed by constructing tunnels for railways and roads where these cross main migration routes for reindeer, and that correspondingly electric and telecommunication wires could be laid as groundcables. Although expensive, such compensatory management should be possible given sufficient time for public discussion and acceptance of the ideas. We further urge the public which take interest in our wild reindeer populations to take up our proposals for debate.

Spencer, H. J.; Port, G. R. 1988. Effects of roadside conditions on plants and insects. II. Soil conditions. Journal of Applied Ecology. 25: 709-715.

Sperry, C. C. 1933. Highway mortality of rabbits in Idaho. Journal of Mammalogy. 14: 260-266.

Stanley, T. R. 1991. Effects of roadside habitat and fox density on a snow track survey for foxes in Ohio. Ohio Journal of Science. 91(5): 186-190.
The reliability of a snow track survey method for foxes was evaluated by investigating whether the average number of road crossings per fox is influenced by changes in roadside habitat or changes in fox density. Field work was conducted from mid-January to mid-February 1984 in Geauga County and Licking County, Ohio.

Starrett, W. C. 1938. Highway casualties in central Illinois during 1937. Wilson Bulletin. 50: 193-196.

Statham, M.; Statham, H. L. 1997. Movements and habits of brushtail possums (*Trichosurus vulpecula* Kerr) in an urban area. Wildlife Research. 24(6): 715-726.
Brushtail possums were studied in an urban area of Launceston, Tasmania, with 23 individuals being radio-tracked over a 12-month period. These animals used a total of 80 different day sites mainly in or under buildings. Convex-polygon home-range areas averaged 10.9 ha for males and 2.0 ha for females, with average nightly movements of 411 and 315 m, respectively. Births occurred in all months of the

year, with a major peak between January and May and a smaller one between August and October. Nine of the 23 individuals were killed and another two injured on roads by cars. It was concluded that total-removal trapping of urban possum populations is not feasible.

Stelfox, J. 1972. Effects of roads and railways on native ungulates. Edmonton, Alberta: Canadian Wildlife Service. [Pages unknown].

Stevenson, J. A. 1996. Florida's ecosystem management and wildlife. In: Evink, G.; Ziegler, D.; Garrett, P.; Berry, J., eds. Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors: Proceedings of the Florida Department of Transportation/Federal Highway Administration transportation-related wildlife mortality seminar; 1996 April 30-May 2; Orlando, FL. FHWA-PD-96-041. Washington, DC: U.S. Department of Transportation, Federal Highway Administration: 273-277.
The author describes greenway and land acquisition programs and provides a description of the conflict between smoke management and road safety during natural or prescribed fire as interfering with ecosystem management in parts of Florida. He also cites drainage problems (culverts and storm run-off) as contributing to problems in aquatic systems.

Stone, Graeme. 1992. Roadside management within vic roads - an overview. Victorian Naturalist. 109(4): 111-115.

Stoner, D. 1925. The toll of the automobile. Science. 61: 56-58.

Storer, T. I.; True, G. H. 1931. Deer proof fences in California. California Fish and Game. 17: 263-269.
The authors provide construction specifications and evaluations of 25 deer fences.

Stout, R. J.; Stedman, R. C.; Decker, D. J.; Knuth, B. A. 1993. Perceptions of risk from deer-related vehicle accidents: implications for public preferences for deer herd size. Wildlife Society Bulletin. 21: 237-249.

Straka, Ulrich. 1995. Contribution to frequency and seasonal distribution of road kills of long-eared owl (*Asio otus*) and tawny owl (*Strix aluco*). Egretta. 38(2): 130-132.

Straker, A. 1998. Management of roads as biolinks and habitat zones in Australia. In: Evink, G. L.; Garrett, P.; Zeigler, D.; Berry, J., eds. Proceedings of the international conference on wildlife ecology and transportation; 1998 February 10-12; Ft. Myers, FL. Tallahassee, FL: Florida Department of Transportation: 181-188.
This article summarized the management of roads in Australia and recognizes the contribution of road reserves to habitat connectivity and as biolinks.

Stuart, A. N. 1991. How can the edge effect be minimized. In: Saunders, D. A.; Hobbs, R. J., eds. Nature conservation 2: the role of corridors. Chipping Norton, Australia: Surrey Beatty and Sons: 417-418.

Sutton, Patricia. 1996. Road mortality of n. saw-whet owls in southern New Jersey, winter 1995-96. New Jersey Audubon Record of New Jersey Birds. 22(2): 31-32.

Swanson, C. S.; Loomis, J. 1998. Economic values associated with roaded and non-roaded recreation areas in the Pacific Northwest. In: Evink, G. L. ; Garrett, P.; Zeigler, D.; Berry, J., eds. Proceedings of the international conference on wildlife ecology and transportation; 1998 February 10-12; Ft. Myers, FL. Tallahassee, FL: Florida Department of Transportation: 53-65.
Recreation in the Pacific Northwest is a valuable resource. In 1990, recreation in western Oregon, western Washington and northern California on Forest Service and Bureau of Land Management lands generated $1.6 billion of public benefits and resulted in expenditures of $2.8 billion. Under current management, recreation demand will exceed supply in primitive, semiprimitive nonmotorized and

semiprimitive motorized management areas. The greatest gap in meeting demand will occur in semiprimitive nonmotorized recreation areas. In this paper, four management scenarios are compared to current Forest Service and Bureau of Land Management management plans and the ability of each to meet future recreation demand is addressed.

Swihart, R. K.; Slade, N. A. 1984. Road crossing in *Sigmidon hispidus* and *Microtus ochrogaster*. Journal of Mammalogy. 65(2): 357-360.
The authors report that a very lightly used single lane dirt road in Kansas was a barrier to prairie vole and cotton rat movement. Out of 823 cotton rats and 1,865 prairie voles captured over 9 years, only 47 cotton rats and 23 prairie voles crossed the road. It was found that 92% of prairie voles and 81.5% of cotton rats captured near the road moved away from the road, and found that animals did not incorporate the road into their home range.

Tabor, R. K. 1978. Motorways and the biologist. London, England: North East London Polytechnic, Motorway Research Project. 176 p.

Taille, J. Y. 1993. TGV network and the environment. In: High speed ground transportation systems I: proceedings of the first international conference on high speed ground transportation systems; 1992 October 25-28; Orlando, FL. Orlando, FL: Department of Transportation: 136-145.
The French TGV network construction shows that the conservation of the environment can be managed in a cost-effective way. Different aspects of the environmental impact of the high speed rail are discussed here including use of environmentally safe energy, protection of the hydrographic network, protection of wildlife, and prevention of noise.

Tarburton, M. K. 1972. Death on the roads. Wildlife in Australia. 9(1): 8-10.

Taskula, K.; Oy, S. 1997. The moose ahead. Traffic Technology International.: 170-173.
The authors describe a fibre-optic lighted moose crossing warning sign. Triggered by motion detectors, the sign is activated when moose are in the crossing zone.

Taylor, M. E. 1971. Bone disease and fractures in east African *viverrids*. Canadian Journal of Zoology. 49: 1035-1042.

Tewes, M. E.; Blanton, D. R. 1998. Potential impacts of international bridges on ocelots and jaguarundis along the Rio Grande Wildlife Corridor. In: Evink, G. L.; Garrett, P.; Zeigler, D.; Berry, J., eds. Proceedings of the international conference on wildlife ecology and transportation; 1998 February 10-12; Ft. Myers, FL. Tallahassee, FL: Florida Department of Transportation: 135-139.
The endangered ocelot (*Leopardus pardalis*) and jaguarundi (*Herpailurus yaguarondi*) occupy the Lower Rio Grande Valley of extreme southern Texas. The passage of the North American Free Trade Agreement has resulted in the proposal or construction of several international bridges linking Texas and Mexico. However, these bridges may be a significant barrier to wildlife movements across the federally-designated Rio Grande Wildlife Corridor. Our understanding of the landscape ecology of ocelots is discussed to better describe the possible significance of the coastal corridor with the Rio Grande Wildlife Corridor. We identify potential direct and indirect impacts of the bridge-roadway systems upon felid populations, habitats, and landscapes. A recently completed study of bobcats (*Lynx rufus*) spatial patterns near international bridges suggests possible confinements of individual felids. Conservation strategies that can be incorporated into bridge projects include "cat underpasses," development of corridor networks, restoration of key habitat tracts, and application of screens for audio and visual disturbances. Finally, the Port of Brownville International Bridge is used as a model for resolving a potentially difficult conflict between endangered cats and construction of an international bridge.

Thiel, R. P. 1985. Relationship between road densities and wolf habitat suitability in Wisconsin. American Midland Naturalist. 113: 404-407.
The author reports that wolf distribution was correlated with low road density.

Thomas, A. E. 1998. The effects of highways on western cold water fisheries. In: Evink, G. L.; Garrett, P.; Zeigler, D.; Berry, J., eds. Proceedings of the international conference on wildlife ecology and transportation; 1998 February 10-12; Ft. Myers, FL. Tallahassee, FL: Florida Department of Transportation: 249-252.
Impacts of highways to terrestrial wildlife are often obvious; the bodies are on the roadway. Impacts to fishes are often more difficult to identify, may be more complex, and usually are accumulative. Improved highway networks have followed human development of the west and have impacted cold water fishes through loss of habitat, changes in habitat quality, isolation of populations, reduced population of both fish species and invertebrate food supplies, and changes in species makeup of aquatic systems. Major changes in habitat conditions can occur from highway improvements such as bank stability and channelization, placement of bridge supports, adding sediment and rocks to stream systems in cleanups from storm damage, or widening projects. The problem of improperly designed and installed culverts as barriers to fish migration is fairly well known. Less well known are other impacts from culverts such as head cutting in side canyons, genetic isolation of fishes, erosion, and habitat loss. Road maintenance can cause habitat degradation through sedimentation of spawning gravels and runoff from salt mixtures can decrease desirable types of aquatic invertebrates. Damage from natural disasters such as flooding often result in rapid and massive cleanup and improvement work; accumulative impacts adversely affecting aquatic systems rarely attracts notice and may have greater importance to the ecosystem health and possible survival of rate species of fish.

Thomas, J. W. ed. 1979. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. Agric. Handb. 533. Washington, DC: U.S. Department of Agriculture, Forest Service. 512 p.

Thompson, J. R.; Rutter, A. J. 1986. The salinity of motorway soils: IV. effects of sodium chloride on some native British shrubs species, and the possibility of establishing shrubs on the central reserves of motorways. Journal of Applied Ecology. 23: 299-315.

Thompson, J. R.; Rutter, A. J.; Ridout, P. S. 1986. The salinity of motorway soils. I. variation in time and between regions in the salinity of soils on central reserves. Journal of Applied Ecology. 23: 251-267.

Thompson, J. R.; Rutter, A. J.; Ridout, P. S. 1986. The salinity of motorway soils. II. distance from the carriageway and other sources of local variation in salinity. Journal of Applied Ecology. 23: 269-280.

Thurber, J. M.; Peterson, R. O.; Woolington, J. D.; Vuctich, J. A. 1992. Coyote coexistence with wolves on the Kenai Peninsula, Alaska. Canadian Journal of Zoology. 70(12): 2492-2498.
Coyote food habits, home range, and interactions with wolves were examined on the Kenai Peninsula, Alaska (USA), (1976 to 1980) to determine mechanism of competition between the two species. Scat analyses (percent frequency occurrence) indicated coyotes relied primarily on snowshoe hare, porcupine, and small mammals. Coyote home ranges overlapped those of wolves and averaged 104.0 ∀ 44.6 (SE) and 70.2 ∀ 10.4 km^2 for males and females, respectively. The ratio of coyotes to wolves captured on public roads was 10:1, while the ratio on roads closed to vehicle access was 0.71:1. Eight instances of wolves killing coyotes are reported. Lack of or minimal exploitation competition appears to allow coexistence of wolves and coyotes, while interference competition is believed to account for the difference in canid abundance near the two road types.

Thurber, J. M.; Peterson, R. O.; Drummer, T. D.; Thomasma, S. A. 1994. Gray wolf response to refuge boundaries and roads in Alaska. Wildlife Society Bulletin. 22: 61-68.
The response of gray wolves to different road types and human presence at the boundaries of Kenai National Wildlife Refuge, Alaska, was examined in a study of radio-collared wolves in 1976 to 1979. Wolf activity within discrete distances up to 5 kilometers from roads and boundaries was computed. Wolves avoided oilfield access roads open to public use (P = 0.001), yet they were attracted to a gated

pipeline access road (P = 0.013) and secondary gravel roads (P = 0.048) with limited human use. Wolf response to a major public highway was equivocal, perhaps because wolves used a den only 1 kilometer away. There was no detectable difference in wolf use of land on either side of the eastern refuge boundary adjacent to national forest lands (P = 0. 82), but on the western, settled boundary wolves used refuge lands more than adjacent private land (P < 0.001). Our data suggest that wolf absence from settled areas and some roads was caused by behavioral avoidance rather than direct attrition resulting from killing of animals.

Tierson, W. C. 1969. Controlling deer use of forest vegetation with electric fences. Journal of Wildlife Management. 33: 922-926.

Tischner, K. 1977. Road kills of south Jersey. Cassinia. 57: 22-24.

Titus, Tom A. 1991. Use of road-killed amphibians in allozyme electrophoresis. Herpetological Review. 22(1): 14-16.

Tracy, D. M.; Dean, F. C. 1978. Possible wildlife responses to stipulated highway design criteria for Mount McKinley National Park road. Final report. [Location of publisher unknown]: U. S. National Park Service, Mount McKinley National Park; [Pages unknown].

Traverso-Martinez, J. M. 1992. Animals run over on the roads of south east Madrid community. In: Lopez, Redondo, ed. I jornadas para el estudio y prevencion de la mortalidad de vertebrados en carreteras, Madrid, 5 y 6 de Octubre de 1991. Tomo 2. [Sessions in the study of prevention of road mortalities of vertebrates, Madrid, 5 and 6 October, 1991. Volume 2.]. Ambiental, Madrid: Coordinadora de Organizacciones de Defensa: 160-167.

Treweek, J.; Veitch, N. 1996. The potential application of GIS and remotely sensed data to the ecological assessment of proposed new road schemes. Global Ecology and Biogeography Letters. 5(4-5): 249-257. Wildlife habitats in the United Kingdom are both limited, and severely threatened by development. Legislation on environmental assessment (EA) offers opportunities for ecological considerations to be taken into account in the planning and design of new developments, but the ability to quantify potential ecological impacts has been hampered by the complexities of dealing with large volumes of spatially referenced data. Linear developments such as roads present particular problems for ecological assessment, because they often affect many habitat types and exert influences at a range of scales. This paper describes an approach to the ecological assessment of proposed road developments based on systematic spatial analysis of the relationship between roads and selected categories of land cover derived from satellite imagery. The impacts of two hypothetical route options on the distribution and area of these categories are assessed both in relation to each other and to regional baseline conditions, in order to estimate cumulative impacts of road development in the region. Local and regional impacts are quantified in terms of land-take and habitat fragmentation for those categories considered most important for nature conservation: broadleaved woodland and lowland heathland. The results of the study suggest that remotely sensed land cover data, in conjunction with a geographical information system (GIS), can be used to improve the effectiveness of ecological assessment techniques for certain habitat types at the landscape level. By developing cost-effective methods for ecological assessment of route options, it is hoped that ecological considerations can be incorporated into the design and planning process for new road developments at an earlier stage, making it possible to avoid cumulative loss of vulnerable habitats at the regional level, and to incorporate effective mitigation measures into the design of preferred options.

Ty, Matti. 1979. Effect of highway traffic on tetraonid densities. Ornis Fenn. 56(4): 169-170.

Tyning, T. F. 1989. Amhersts tunneling amphibians. Defenders. Sept./Oct.: 20-23.

Tyson, R. M. 1980. Road killed platypus. The Tasmanian Naturalist. 60: 8-10.

Uekermann, E. 1984. Untersuchung der Eignung von Wilddurchlassen und der Wirksamkeit von Wildwarnreflektoren. Forschung Strassenbau und Strassenverkehrstechnik. 426: 1-58.
The author studied crossing use by ungulates at 824 structures with fences along 49 stretches of highways in Germany. It was found that reflectors reduce collisions 20 to 40% but are expensive to maintain.

Ujvári, M; Baagøe, H. J.; Madsen, A. B. 1998. Effectiveness of wildlife warning reflectors in reducing deer-vehicle collisions: a behavioral study. Journal of Wildlife Management. 62(3): 1094-1099.
Habituation of fallow deer (*Dama dama*) to light reflections from WEGU reflectors was examined. The experimental design eliminated factors normally associated with light reflections (vehicle noise, light), and deer were exposed to light reflections at predetermined time intervals. Reactions to light were variable, however, deer exhibited increasing indifference to reflections. Habituation of deer and technical limitations of the reflectors, such as limited angle and low light intensity of the reflection, mean that reflectors are not reliable as a method to reduce the number of deer-vehicle accidents on a long-term basis.

Ullmann, I.; Bannister, P.; Wilson, J. B. 1995. The vegetation of roadside verges with respect to environmental gradients in southern New Zealand. Journal of Vegetation Science. 6(1): 131-142.
A survey of the vegetation of roadside verges was made across the southern part of the South Island of New Zealand. Samples were taken at 10-kilometer intervals along selected roads providing a climatic range from the suboceanic conditions of the east coast into semi-arid Central Otaoo, and from Central Otago through the Southern Alps to the hyperoceanic areas of high rainfall on the west Coast. The variation in the floristic composition is associated mainly with variation in rainfall, continentality, altitude, soil acidity, soil organic matter, and presence of forest. Sites in the arable and pastoral regions on the eastern side of the Southern Alps support a herbaceous vegetation consisting mostly of exotic species of European origin, with a few native grasses scattered through the drier and less fertile sites. A greater proportion of native species is found at higher altitudes. Roadside vegetation in the area of high rainfall to the west is characterized by indigenous ferns and woody species, although vegetation adjacent to cleared areas is more similar to that on roadsides adjacent to farmland on the east coast. The pattern of distribution of both native and exotic species is strongly related to altitudinal and climatic gradients, and the environmental responses of the exotic species are similar to those recorded in Europe. This suggests a colonization of all available sites by the exotic species, despite the relatively short time since their introduction to New Zealand, rather than an incomplete invasion.

van Boheman, H. D. 1995. Mitigation and compensation of habitat fragmentation caused by roads: strategy, objectives, and practical measures. Transportation Research Record. 1475: 133-137.
The author reports experiences with the Dutch Second Transport Structure Plan. Habitat fragmentation mitigation techniques being used in the Netherlands are reviewed, including landscape design, overpasses, culverts, and amphibian tunnels.

van der Grift, E. A.; Kuijsters, R. 1998. Mitigation measures to reduce habitat fragmentation by railway lines in the Netherlands. In: Evink, G. L.; Garrett, P.; Zeigler, D.; Berry, J., eds. Proceedings of the international conference on wildlife ecology and transportation; 1998 February 10-12; Ft. Myers, FL. Tallahassee, FL: Florida Department of Transportation: 166-170.
Rail infrastructure contributes to the fragmentation of wildlife habitats in the Netherlands. Plans for a large-scale extension of the Dutch railway network and an intensification of track use have made this problem even more serious. This most important fragmentation effects of railway lines for fauna are the loss of habitat, mortality, barrier formation, and disruption in general As a result, habitats are reduced or become isolated from each other. This means that the chance of survival of (sub)populations is decreased. A large range of measures may contribute to a reduction of the fragmenting effect of rail infrastructure. These measures, as this article shows through practical examples, include: a restoration or development of a (substitute) habitat, placing wildlife fences as a protection against railway lines, constructing fauna passageways, and sound reducing provisions. Railways also offer opportunities for defragmentation. By taking nature-oriented measures along

railway lines they may have the function of habitat, refuge, or corridor. Mitigation measures in rail projects are on the one hand aimed at minimizing the fragmenting effect of railway lines, and on the other hand at utilizing the opportunities for defragmentation in an optimal way.

van der Reest, P. J. 1992. Small mammal fauna of road verges in the Netherlands: ecology and management. Lutra. 35(1): 1-27.

van der Zande, A. N.; ter Keurs, C. J.; van der Weidjen, W. J. 1980. The impact of roads on the densities of four bird species in an open field habitat - evidence of a long distance effect. Biological Conservation. 18: 299-321.

van der Zee, F. F.; Wiertz, J.; Ter, C. J. and others. 1992. Landscape change as a possible cause of the badger (*Meles meles* l.) decline in the Netherlands. Biological Conservation. 61(1): 17-22.
This study analyses the considerable decline of the badger (*Meles meles*) population in the Netherlands. Between 1960 and 1980 the number of used setts decreased by more than 30%. Changes in the landscape from 1960 to 1980 were thought to be an important cause of this decline. In 20 years many small landscape elements such as hedgerows, old orchards and small woods have been cleared, while the network of roads and traffic have increased. Three statistical analyses were carried out to relate the change in the number of used badger setts to the change in landscape, the latter expressed in several variables measured on topographical maps. The number of roads was most closely related to the decline of the badger. The change in the number of small landscape elements appeared to be of minor importance. The number of badger setts has declined more in open landscape than in woodland. This study clearly demonstrates the importance of the number of roads as a major factor in the decline of badgers in the Netherlands. Roads form barriers for badgers in their daily movements within the home range and on dispersal, causing many traffic casualties. This indicates the importance of the construction of badger tunnels, and above all the need for thorough and careful planning of public transport facilities and road building.

Van Dyke, F. B.; Brocke, R. H.; Shaw, H. G. and others. 1986. Reactions of mountain lions to logging and human activity. Journal of Wildlife Management. 50(1): 95-102.
Reactions of mountain lions to logging and to various human activities were studied in northern Arizona from 1976 to 1980 and in southcentral Utah from 1979 to 1982. Resident mountain lions rarely were found in or near (1 km) sites logged within the past 6 years. Younger (2 or 3 year old) mountain lions were found in logged areas more often than older mountain lions but four of five young mountain lions showed peak activity <2 hours of sunset and sunrise. Near human presence, lion activity peaks shifted to after sunset. Other activity was concentrated during night hours, and there was no peak of activity at sunrise. Dispersing juvenile mountain lions encountered human disturbances more frequently than resident lions ($P<0.05$). Established residents and young mountain lions that ultimately became residents selected home areas with road densities lower than the study area average, no recent timber sales, and few or no sites of human residence. All disturbances examined appeared to have at least potential adverse impacts on mountain lions, especially on dispersing juveniles.

Van Dyke, Fred G.; Rainer, H. B.; Harley, G. S. 1986. Use of road track counts as indices of mountain lion presence. Journal of Wildlife Management. 50(1): 102-109.

van Esterik, N.; Martens, G. J.; Zonderl, A. N.; Zuiderwijk, A. 1989. Tunnels for migrating *Bufo bufo* in Overveen. Lacerta. 7(3): 74-80.

van Gelder, J. J. 1973. A quantitative approach to the mortality resulting from traffic in a population of *Bufo bufo* l. Oecologica (Berl.). 13(1): 93-95.
The author report 30% of female toads were killed while crossing with 9.4 cars/hour traffic.

van Leeuwen, B. H. 1982. Protection of migrating common toad (*Bufo bufo)* against car traffic in The Netherlands. Environmental Conservation. 9: 34-41.

In several places in the Netherlands, measures are being taken to prevent the killing of common toads by car traffic. The number of actions has grown to about 20 in 1981. Most actions involve volunteer efforts to manually pick up toads and move them across roads during migration.

van Riper, C.; Ockenfels, R. 1998. The influence of transportation corridors on the movement of pronghorn antelope over a fragmented landscape in northern Arizona. In: Evink, G. L.; Garrett, P.; Zeigler, D.; Berry, J., eds. Proceedings of the international conference on wildlife ecology and transportation; 1998 February 10-12; Ft. Myers, FL. Tallahassee, FL: Florida Department of Transportation: 241-248.
We studied distribution and movement patterns of 37 radio-collared pronghorn antelope within the environs of three national parks in Arizona, analyzing and modeling data with an Arc Info geographic information system. Differences in movement patterns were in large part determined by major transportation corridors and the amount of habitat fragmentation caused by those corridors within our study areas. Aside from pronghorn gender differences, individual animal and herd movements were specifically influenced by fencing along main thoroughfares, rates of traffic and train flows, historical animal presence, and permanently available water sources. If pronghorn are to be properly managed over a large fragmented landscape in northern Arizona, managers will have to alter several of their present land management practices. Potential changes will have to deal with how pronghorn are harvested and how to provide acceptable movement corridors so that connection can occur among presently genetically isolated groups of animals.

van Sickle, W. D.; Lindzey, F. G. 1992. Evaluation of road track surveys for cougars (*Felis concolor*). Great Basin Naturalist. 52(3): 232-236.
Road track surveys were a poor index of cougar density in southern Utah. The weak relationship we found between track-finding frequency and cougar density undoubtedly resulted in part from the fact that available roads do not sample properly from the nonuniformly distributed cougar population. However, the significantly positive relationship (r2 = .73) we found between track-finding frequency and number of cougar home ranges crossing the survey road suggested the technique may be of use in monitoring cougar populations where road abundance and location allow the population to be sampled properly. The amount of variance in track-finding frequency unexplained by number of home ranges overlapping survey roads indicates the index may be useful in demonstrating only relatively large changes in cougar population size.

Varland, D. E.; Klaas, E. E.; Loughin, T. M. 1993. Use of habitat and perches, causes of mortality and time until dispersal in post-fledging American kestrels. Journal of Field Ornithology. 64(2): 169-178.
The use of habitat and perches, causes of mortality and time until dispersal of American Kestrels (*Falco sparverius*) after they fledged from nest boxes on the backs of highway signs were studied along Interstate 35 in central Iowa. Between 1988 and 1990, radio-transmitters were attached to 61 nestlings in 47 nests just before nest departure. During the first week after fledging and before hunting began, kestrels spent substantial amounts of time perched on the ground along the interstate right-of-way and in row-crop fields. All but one of the 16 kestrels found dead died during the first week after they fledged, before their flying skills had developed. Mammalian predation accounted for six of the deaths and was the main cause of mortality. Only two deaths resulted from collisions with vehicles on the interstate. After the first week, fledgling kestrels began hunting along secondary roads and increased the use of this habitat throughout the 4 weeks birds were observed. Mean time until the initiation of dispersal was 22.7 days after fledging. Only one of 17 birds recaptured in a nest box as a breeding bird was banded as a nestling.

Varland, K. L.; Schaefer, P. J. 1998. Roadside management trends in Minnesota. In: Evink, G. L.; Garrett, P.; Zeigler, D.; Berry, J., eds. Proceedings of the international conference on wildlife ecology and transportation; 1998 February 10-12; Ft. Myers, FL. Tallahassee, FL: Florida Department of Transportation: 214-228.
Minnesota's Roadsides for Wildlife Program (RFW) was initiated in 1984 to promote roadside habitat awareness, reduce spring/summer roadside disturbance, and improve quality of roadside habitat. Special roadside management surveys completed in 1973 and 1983 indicated that roadside disturbance

was negatively impacting wildlife habitat on more than 40% of roadsides. Each August, since 1984, the RFW Program conducted a management survey that coincides with the DNR's roadside wildlife counts to measure the program's impacts and determine management trends. Roadside mowing dominated roadside disturbance. Disturbance has averaged a 19% decline impacting 42,450 hectares since the beginning of the program. A 1985 roadside mowing law has resulted in reduced roadside mowing. Weather is also a factor. Undisturbed roadside vegetation has remained relatively stable since 1987. The greatest reductions in roadside disturbance have occurred in east-central and west-central regions. The peak mowing activity during summer has remained the same since 1984 with about 80% occurring during July 1 to 31. Other disturbance factors (lawns and agricultural encroachment) have increased in east-central, south-central, and west-central regions. Poor quality nesting cover remained relatively stable from 1992 to 1997 and averaged about 16% of roadsides surveyed. Good quality cover increased from 25% to 45% and moderate quality cover declined during this period. A public relations approach to roadside management has brought about changes in legislation, mowing behavior, and greater participation by road authorities. Future program emphasis will include integrated roadside vegetation management and increased use of native prairie vegetation.

Vassant, J.; Brandt, S.; Jullien, J. M. 1993. Effects of the wildlife passage over motorway A5 on the populations of red deer and wild boar in the Massif d'Arc-en-Barrois. Part 2: case of the population of wild boar. Bull. Mens. Office Natl. Chasse. 184: 24-33.

Velazquez, A. 1993. Man-made and ecological habitat fragmentation: study case of the volcano rabbit (*Romerolagus diazi*). Zeitschrift Fuer Saeugetierkunde. 58: 54-61.
Documented the fragmentation of the habitat of the volcano rabbit (*Romerolagus diazi*). Two different processes of fragmentation are illustrated, namely; man-made and ecological. Man-made fragmentation has occurred through splitting the original distribution range into islands by highway construction, farming, and intensive burning and grazing activities. The ecological fragmentation is due to environmental discontinuity, which is reflected in a mosaic of vegetational communities or habitats. The ecological amplitude of the habitat types has been analyzed by canonical correlation analysis. Six habitat types were distinguished. Habitat type 2, open pine woodland (*Pinus hartwegii-Festuca tolucensis*) habitat type 3 mixed alder pine forest (*Alnus firmifolia-Muhlenbergia macroura*) and habitat type 4, pine forest (*Pinus* spp. *Muhlenbergia quadridentata*) provide most of the suitable ecological conditions for the survival of the volcano rabbit. The two processes of fragmentation habitat are threatening the survival of this endangered Mexican lagomorph. These two habitat fragmentation processes are discussed in light of their role in conservation and management.

Venner, D. 1978. Influence of deer mirrors on road linked mortality of deer. In: Tabor, R. K., ed. Motorways and the biologist. London, England: North East London Polytechnic, Motorway Research Project: 31-36.

Ventry, W. F. 1995. Value engineering summary of the wildlife crossings WPI No. 1114163, State project no. 03080-3519, Collier County, Florida, June 5-9, 1995. Orlando, FL: Florida Department of Transportation 63 p.
The author describes Highway 29 crossing structures for panthers in southern Florida.

Verboom, J.; Metz, J. A.; Meelis, E. 1993. Metapopulation models for impact assessment of fragmentation. In: Vos, C. C.; Opdam, P., eds. Landscape ecology of a stressed environment. London: Chapman and Hall: 172-189.

Vermeulen, H. J. W. 1993. The composition of the carabid fauna on poor sandy road-side verges in relation to comparable open areas. Biodiversity and Conservation. 4: 331-350.

Vermeulen, H. J. W. 1994. Corridor function of a road verge for dispersal of stenotopic heathland ground beetles (*Carabidae*). Biological Conservation. 69: 339-349.
To reduce the effects of habitat isolation dispersal corridors between habitat fragments are often proposed. In this study the corridor function of a poor sandy roadside verge, adjacent to an open area

of drift sand, was investigated for ground-dwelling arthropods. Three species of carabid beetles characteristic of this habitat (*Ptersotichus lipidus, Harpalus servus* and *Cymindis macularis*) were marked and released at four different sites. Exchange of individuals of these species was recorded between the road verge and the open sandy area, and dispersal along the road verge was established. The rate of movement along the road verge was low compared to that in the open area. Sites with trees and narrow sites at the road verge had a barrier effect. Reproduction was recorded for two species at broad areas in the road verge. Under certain conditions (re)colonization of habitat areas by dispersal along a long, ribbon-like habitat might occur. For each species the specific features of such a corridor is discussed.

Vestjens, W. J. 1973. Wildlife mortality on a road in New South Wales. Emu. 73(3): 107-112.

Villey-Desmeserets, F. 1988. Road and environment: assessment and outlook. Travaux.(638): 2-4.
As concerns the transport infrastructures, the works are often costly and efforts to take the environment into account can be expensive. While savings are always desirable, the Ministry of the Environment must not hesitate and must endeavor to obtain correct results. The author attempts to outline an overall picture of the present situation in France, describing the decision-making process as concerns roads. He also indicates what would be desirable and reports on observations in connection with the choice of the preparation and implementation of a project, closing the article with eight proposals.

Virgos, Cantalapiedra E. 1992. Mammal mortality on roads. Up to the moment information compilation by PMVC. In: Lopez, Redondo, ed. I jornadas para el estudio y prevencion de la mortalidad de vertebrados en carreteras, Madrid, 5 y 6 de Octubre de 1991. Tomo 2. [Sessions in the study of prevention of road mortalities of vertebrates, Madrid, 5 and 6 October, 1991. Volume 2.]. Ambiental, Madrid: Coordinadora de Organizacciones de Defensa: 49-64.

Vlasin, R. D.; Davis, P. 1978. Ecological effects of highway construction upon Michigan woodlots and wetlands. Phase II report. East Lansing, MI: Michigan State University, Agricultural Experiment Station.; FHWA/MI78/3153. 271 p. Sponsored by: Federal Highway Administration, Michigan Division, Lansing, MI, and Michigan Department of State Highways and Transportation, Lansing, MI.
To determine the ecological effects of highway construction upon Michigan woodlots and wetlands, 10 sites located along a 95 mile segment of I-75 between Roscommon and West Branch were studied. In Phase I, these sites were examined in respect to several natural science parameters. Soils, hydrology, water quality, forestry and wildlife. This study provided a continued evaluation, analysis and interpretation of data developed during Phase I where required additional data was obtained and correlated. A conceptual framework built in ecological principles for objectively evaluating key interrelationships having natural science parameters, as they relate to environmental impacts resulting from highway construction, is presented in the study.

Volf, Bohumil. 1986. The game animals and the transport communications. Pr. Vyzk. Ustavu Lesn. Hospod. Myslivosti (Strnady). 68(2): 337-355.

Voorhees, L. D. 1976. Waterfowl nesting: highway right-of-way mowing versus succession. Bismarck: North Dakota State University. 98 p. Ph.D. dissertation.

Wade, K. J.; Flanagan, J. T.; Currie, A.; Curtis, D. J. 1980. Roadside gradients of lead and zinc concentrations in surface-dwelling invertebrates. Environmental Pollution (Series B). 1: 87-93.

Waechter, Antoine. 1979. Animal mortality on a high traffic road. Mammalia. 43(4): 577-579.

Wagner, Paul; Carey, Marion; Lehmkuhl, John 1998. Assessing habitat connectivity through transportation corridors on a broad scale: an interagency approach. In: Evink, G. L.; Garrett, P.; Zeigler, D.; Berry, J., eds. Proceedings of the international conference on wildlife ecology and transportation; 1998 February 10-12; Ft. Myers, FL. Tallahassee, FL: Florida Department of Transportation: 66-67.
Highways have long been considered to have an adverse impact on wildlife, but until recently very

little work has been completed to determine how to minimize these impacts. The highway/wildlife impact recently became an issue in Washington State when the U.S. Forest Service designated a portion of Wenatchee and Mount Baker-Snoqualmie National Forests as an adaptive management area (AMA). A major management objective for this area is providing habitat connectivity. Interstate 90, the major east-west transportation corridor in Washington State, passes through the Wenatchee and Mt. Baker-Snoqualmie National Forests, in the AMA, posing a challenge to meeting their mandated requirement to maintain habitat connectivity through the Snoqualmie Pass AMA. Consideration of these issues lead to the partnering of the Forest Service and the Washington State Department of Transportation (WSDOT) in a joint study which will identify ways to provide for habitat connectivity across the highway. The goal of the study is to examine the relationships between wildlife and interstate highways corridors, in terms of habitat connectivity and human safety, then use that information in conjunction with a complementary Forest Service landscape study to develop a general methodology for integrating transportation and landscape planning. The study will determine where connectivity corridors are located and where they should be maintained within the study area. Management strategies and techniques will be developed which will facilitate both organizations in meeting their goals of providing habitat connectivity while providing for a safe and cost effective transportation system for the people of Washington State.

Walder, B. 1998. About wildlands CPR. In: Evink, G. L.; Garrett, P.; Zeigler, D.; Berry, J., eds. Proceedings of the international conference on wildlife ecology and transportation; 1998 February 10-12; Ft. Myers, FL. Tallahassee, FL: Florida Department of Transportation: 234-235.
This paper describes the activities of the Wildlands Center for Preventing Roads, Wildlands CPR group. This groups is a national network of grassroots groups and individuals working to reverse the severe ecological impacts of wildland roads.

Wallin, D. O. 1997. Effects of forest roads on populations and movement patterns of small mammals in the Northern Cascades: a grant proposal. Bellingham, WA: Western Washington University 43 p.

Walro, J. M. 1976. Analysis of deer-vehicle accidents in southeastern Ohio. Athens: Ohio University. 19 p. M.S. thesis.

Warburton, G. S.; Maddrey, R. C.; Rowe, D. W. 1993. Characteristics of black bear mortality on the coastal plain of North Carolina. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies. 47: 276-286.

Ward, A. L.; Cupal, G. A.; Goodwin, G. A.; Morris, H. D. 1976. Effects of highway construction and use on big game populations. Washington, DC: U.S. Department of Transportation, Federal Highway Administration; FHWA-RD-76-174. 92 p.

Ward, A. L. 1980. Effects of highway operation practices and facilities on elk, mule deer and pronghorn antelope. Fort Collins, CO: Rocky Mountain Forest and Range Experiment Station.

Ward, A. L.; Fornwalt, S. E.; Henry, S. E.; Hodorff, R. A. 1980. Effects of highway operation practices and facilities on elk, mule deer, and pronghorn antelope. Washington, DC: U.S. Department of Transportation, Federal Highway Administration; FHWA-RD-79-143. 48 p.
This report documents the effects of I-80 passing through deer, elk and pronghorn winter range in Wyoming. Fencing and crossing structures were installed; deer used the structures but antelope did not. Dimensions of the crossing structures are not indicated. They describe the use of a deer detection system and linked sign. Using telemetry heart rate monitoring, they documented that deer and elk were least disturbed by moving vehicles, followed by parked vehicles, followed by people on foot.

Ward, A. L. 1982. Mule deer behavior in relation to fencing and underpasses on Interstate 80 in Wyoming. Transportation Research Record. 859: 8-13.
Mule deer used machinery and box-type underpasses to cross under I-80 since the construction of 8

foot high big-game fencing to replace the regular right-of-way fence. Deer-vehicle accidents have been reduced more than 90% - a significant savings of deer life and vehicle damage. Major difficulties associated with big-game fencing on I-80 were a) overcoming deer anxiety and reluctance to use the underpass the first time, b) extending the high fence to a length great enough to prevent end-runs, c) preventing deer from crossing cattle-guards on the ramps, d) finding and promptly repairing holes either under or through the fence, and e) building one-way gates at the proper distance from the underpass.

Waring, G. H.; Griffis, J. L.; Vaughn, M. E. 1991. White-tailed deer roadside behavior, wildlife warning reflectors, and highway mortality. Applied Animal Behaviour Science. 29: 215-223.
The behavior of white-tailed deer and the effect of Swareflex wildlife highway warning reflectors were studied along a busy two-lane highway in Crab Orchard National Wildlife Refuge, Illinois. Focal-animal observational sampling was conducted through all seasons and for 24 hour/day. After baseline data had been obtained, Swareflex reflectors were installed for 14 months while observational sampling continued. Deer roadkills occurring between dusk and dawn were the same with reflectors deployed as during the 2 years prior to testing, even though the deer population had decreased. Behavior of deer crossing the road did not appear to be altered by the reflectors.

Warner, R. E. 1992. Nest ecology of grassland passerines on road rights-of-way in central Illinois. Biological Conservation. 59: 1-7.
The ecology of nesting by grassland passerines was studied from 1976 to 1984 along rural interstate (four-lane) and secondary road rights-of-way in central Illinois (N = 593 nests). Numbers of nests and species increased with roadside width. The probability of nest survival/day on managed (seeded and unmowed) rural secondary roadsides was 0.970. Densities of passerine nests on roadsides were high where forage crops (prime nest cover) were relatively distant from plots, and in years when small grain production was low. The frequency of nesting on rights-of-way was also affected by seeding type and by mowing regime. For example, fescue *Festuca* spp., the most widely planted roadside vegetation in the Midwest, sustained relatively few breeding birds. The amount of vehicular traffic along secondary roadsides did not influence nest densities. With the expansion of row-crop farming in the Midwestern United States, vegetation along road rights-of- way is critical for sustaining grassland birds that nest in edges and ecotones; roadside should be carefully managed toward this end.

Warner, Richard E. 1983. An adoption model for roadside habitat management by Illinois farmers. Wildlife Society Bulletin. 11(3): 238-249.

Warner, Richard E.; Joselyn, G. B. ; Stanley, L. E. 1987. Factors affecting roadside nesting by pheasants in Illinois. Wildlife Society Bulletin. 15(2): 221-228.

Warner, Richard E.; Larry, M. D.; Stanley, L. E.; Joselyn, G. B. 1992. Costs and benefits of roadside management for ring-necked pheasants in Illinois. Wildlife Society Bulletin. 20(3): 279-285.

Warren, E. R. 1936. Casualties among animals on mountain roads. Science. 83: 14-17.

Warren, E. R. 1936. Mountain road casualties among animals in Colorado. Science. 84: 485-489.

Washburn, E. W. 1925. The toll of the automobile. Science. 61: 56-57.

Waters, D. 1988. Monitoring program, mitigative measures, Trans-Canada Highway twinning, kilometers 0-11.4. Final report. Ottawa, Ontario: Environment Canada - Parks 57 p.

Watkins, Robert O. 1982. Highway impacts on the desert. Environmental Science Applications. 4: 1339-1348.

Watson, J. 1991. Essential criteria for designation of wildlife corridors. In: Saunders, D. A.; Hobbs, R. J., eds. Nature conservation 2: the role of corridors.2. Chipping Norton, Australia: Surrey Beatty and Sons: 403-404.

Watson, Justin. 1992. Dune breeding birds and off-road vehicles. Naturalist (South Africa). 36(3): 8-12.

Watts, B. D.; Bradshaw, D. S. 1994. The influence of human disturbance on the location of great blue heron colonies in the lower Chesapeake Bay. Colonial Waterbirds. 7(2): 184-186.

Way, J. M. 1970. Roads and the conservation of wildlife. Journal of the Institute of Highway Engineers. July: 5-11.
The author provides a summary of the importance of the conservation of roadside habitats in Great Britain.

Way, J. M. 1977. Roadside verges and conservation in Britain: a review. Biological Conservation. 12: 65-74.
A description is given of work developed in the U.K. to estimate the conservation importance of roadside verges. Investigations into management requirements that will satisfy the highway engineers, whilst encouraging wildlife habitats have been made. The importance of liaison between conservation interests and the highway authorities is stressed. Some aspects of the potential for creative conservation of motorway land are discussed, together with the apparent similarity between motorways and railways.

Webb, G. A.; Chapman, W. S. 1983. Nocturnal road basking by gravid female C*acophis squamulosus* and C*ryptophis nigrescens* (Serpentes: elapidae). Herpetofauna. 15(1): 24-29.

Webb, N. R. 1989. Studies on the invertebrate fauna of fragmented heathland in Dorset, U.K., and the implications for conservation. Biological Conservation. 47: 153-165.

Webb, R. H. 1983. Compaction of desert soils by off-road vehicles. In: Webb, R. H.; Wilshire, H. G., eds. Environmental effects of off-road vehicles: impacts and management in arid regions. New York: Springer-Verlag: 51-79.

Wegmann, Samuel. 1991. Conservation of wildlife in integral planning of road construction. Schweiz. Z. Forstwes. 142(8): 627-645.

Weidemann, G.; Reich, M.; Plachter, H. 1996. Influence of roads on a population of *Psophus stridulatus* L. 1758 (Saltatoria, Acrididae). Verhandlungen Der Gesellschaft Fuer Oekologie. 6: 259-267.

Welsh, C. J. E.; Healy, W. M. 1993. Ineffectiveness of Swareflex reflectors at reducing deer-vehicle collisions. Wildlife Society Bulletin. 21: 127-132.

White, R. G.; Yousef, M. K. 1978. Energy expenditure in reindeer walking on roads and on tundra. Canadian Journal of Zoology. 56(2): 215-223.

Whitford, P. C. 1976. Microclimate factors of blacktop roads as they affect bird behavior, diurnal distribution and range. Stevens Point: University of Wisconsin. 27 p. M.S. thesis.

Whitford, P. C. 1985. Bird behaviour in response to the warmth of blacktop roads. Transactions of the Wisconsin Academy of Sciences Arts and Letters. 3: 135-143.

Wickham, J. D.; Wu, J. G.; Bradford, D. F. 1997. A conceptual framework for selecting and analyzing stressor data to study species richness at large spatial scales. Environmental Management. 21(2): 247-257.
In this paper we develop a conceptual framework for selecting stressor data and analyzing their

relationship to geographic patterns of species richness at large spatial scales, Aspects of climate and topography, which are not stressors per se, have been most strongly linked with geographic patterns of species richness at large spatial scales (e.g., continental to global scales). The adverse impact of stressors (e.g., habitat loss, pollution) on species has been demonstrated primarily on much smaller spatial scales. To date, there has been a lack of conceptual development on how to use stressor data to study geographic patterns of species richness at large spatial scales. The framework we developed includes four components: 1) clarification of the terms stress and stressor and categorization of factors affecting species richness into three groups-anthropogenic stressors, natural stressors, and natural covariates; 2) synthesis of the existing hypotheses for explaining geographic patterns of species richness to identify the scales over which stressors and natural covariates influence species richness and to provide supporting evidence for these relationships through review of previous studies; 3) identification of three criteria for selection of stressor and covariate data sets: a) inclusion of data sets from each of the three categories identified in item 1, b) inclusion of data sets representing different aspects of each category, and c) to the extent possible, analysis of data quality; and 4) identification of two approaches for examining scale-dependent relationships among stressors, covariates, and patterns of species richness-scaling-up and regression-tree analyses. Based on this framework, we propose 10 data sets as a minimum data base for examining the effects of stressors and covariates on species richness at large spatial scales. These data sets include land cover, roads, wetlands (numbers and loss), exotic species, livestock grazing, surface water pH, pesticide application, climate (and weather), topography, and streams.

Wiegand, P.; Schropfer, R. 1997. DNA fingerprinting analysis of subpopulations of the red squirrel (*Sciurus vulgaris*, l 1758). Journal of Zoological Systematics and Evolutionary Research. 35(2): 71-74.
The relationships within two squirrel groups of 7 and 10 individuals living in small isolated forest areas (>>20 ha) were studied by DNA fingerprinting. The study area was located in northwestern Germany, close to the town of Osnabruck. The degrees of relationship determined by the multi locus probes 33.15 and MZ1.3 were >>20-40% higher in the two subpopulations compared with a group of unrelated squirrels. The band-sharing rates in the latter group varied between 6 and 57% (33.15) and 17 and 63% (MZ1.3), whereas the squirrels living in the two forest islands had band-sharing rates between 13 and 80%, depending on the probe used. Although the forest islands were isolated by fields and roads, there seemed to be a small genetic exchange between the squirrels of the forest islands and those of the next adjacent larger woodland area.

Wieneke, F.; Schroder, W. 1995. Planning of green bridges at the highway, with special consideration of the brown bear. Munich, Germany: Institute of Geography at Ludwig-Maximilians University. [Pages unknown]. M.S. thesis.

Wilcove, D. S. 1985. Nest predation in forest tracts and the decline of migratory songbirds. Ecology. 66: 1211-1214.

Wilcox, Douglas A. 1989. Migration and control of purple loosestrife (*Lythrum salicaria* l.) along highway corridors. Environmental Management. 13(3): 365-370.

Wilkins, K. T.; Schmidly, D. J. 1980. Highway mortality of vertebrates in southeastern Texas. Texas Journal of Science. 4: 343-350.
Mammals, mostly opossums and armadillos, were 65% of the roadkill found. The kill rate was highest on a state highway with intermediate traffic volume.

Wilkins, K. T.; Schmidly, D. J. 1981. The effects of mowing of highway rights-of-ways on small mammals. In: Tillman, R. E., ed. Proceedings of second symposium on environmental concerns in rights-of-way management; 1979 October 16-18; Ann Arbor, MI. Ann Arbor: University of Michigan: 1-54.

Wilkins, Kenneth T. 1982. Highways as barriers to rodent dispersal. Southwestern Naturalist. 27(4): 459-460.

Wilshire, Howard G.; Shipley, Susan; Nakata, John K. 1978. Impacts of off-road vehicles on vegetation. Transactions of the North American Wildlife Natural Resource Conference. 43: 131-139.

Wince, W. 1987. Badgers on roads. Flycatcher. 8: 18-22.

Witmer, G. W.; de Calesta, D. S. 1985. Effect of forest roads on habitat use by Roosevelt elk. Northwest Science. 9(2): 122-125.

Woelfel, H.; Krueger, H. H. 1995. On the design of game passages across highways. Zeitschrift fuer Jagdwissenschaft. 41: 209-216.
The problem of game passages across highways and other traffic arteries is presented from the available literature and from descriptions of the effectiveness of some such passages in Central Europe. Trials permitting a choice to two differently simulated passage tunnels for game were set up in a fallow deer enclosures to optimize the construction of game passages. Tunnels painted a light color were significantly preferred over dark ones. The installation of artificial lighting and such structures as tree trunks in the dummy tunnels did not improve their acceptance. Recommendations are given for the designing of game passages.

Wolff, J. O.; Schauber, E. M.; Edge, W. D. 1996. Can dispersal barriers really be used to depict emigrating small mammals? Canadian Journal of Zoology. 74: 1826-1830.
Small-mammal enclosure studies have attempted to depict emigrants as animals that are captured after they cross a barrier strip. These "emigrants" are often categorized by age, sex, and reproductive condition. In a similar study with gray-tailed voles (*Microtus canicaudus*), we captured 307 of 1,469 (21%) marked animals across a 1-meter barrier strip. These animals consisted disproportionately of males and subadults, but did not differ in longevity or reproductive condition from animals that did not cross the barrier. Forty-two of 45 animals that were captured ∃ 7 times with ∃ 2 captures across the barrier strip had home ranges adjacent to the barrier. These data suggest that most animals caught across the barrier were not emigrating but were making exploratory movements or had home ranges on the edge of the habitat. We question the use of dispersal barriers in depicting emigrants and recommend caution in interpreting results from previous studies involving dispersal barriers.

Wood, P.; Wolfe, M. L. 1988. Intercept feeding as a means of reducing deer-vehicle collisions. Wildlife Society Bulletin. 16: 376-380.
Feeding may reduce collision rates, but should be used in conjunction with other methods and should not be used long-term because of the potential to attract more animals into the area.

Woodard, T. N.; Reed, D. F.; Green, L. and others. 1972. An evaluation of deer-proof fence length required to prevent deer movement on or across high speed highways. Denver, CO: State of Colorado, Division of Wildlife. [Pages unknown].
A 1.1 mile 8-foot fence was erected along Highway 82 to prevent deer movement across the highway. Prior to installation, the mean number of deer crossings per 24 hour period during March to May 1971 was 12.8 (n=29) with two deer killed on the highway and a mean spotlight count of 47.6 (n=11). In the vicinity of the Vail underpass-fencing complex, sightings of marked deer were used to monitor their movements in relation to the fence.

Woodard, T. N.; Reed, D. F.; Pojar, T. M. 1973. Effectiveness of Swareflex wildlife warning reflectors in reducing deer-vehicle accidents. Denver, CO: State of Colorado, Division of Wildlife. [Pages unknown].

Woodard, T. N. 1976. Deer-auto accident investigations: effects of highway lighting on number of deer killed by vehicles. Denver, CO: State of Colorado, Division of Wildlife. 5 p.

Wooding, J. B.; Brady, J. R. 1987. Black bear roadkills in Florida. Proceedings of the Annual Conference of the Southeast Association of Fish and Wildlife Agencies. 41: 438-442.

Woods, J. 1989. Second progress report: effectiveness of fences and underpasses on the Trans-Canada Highway and their impact on ungulate populations project. Sept. 1985 to May 1988. Ottawa, Ontario: Environment Canada-Parks 97 p.

Woods, J. 1991. Ecology of a partially migratory elk population. Vancouver: University of British Columbia. [Pages unknown]. Ph.D. thesis.

Woods, J.; Munro, R. H. 1996. Roads, rails and the environment: wildlife at the intersection in Canada's western mountains. In: Evink, G.; Ziegler, D.; Garrett, P.; Berry, J., eds. Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors: Proceedings of the Florida Department of Transportation/Federal Highway Administration transportation-related wildlife mortality seminar; 1996 April 30-May 2; Orlando, FL. FHWA-PD-96-041. Washington, DC: U.S. Department of Transportation, Federal Highway Administration: 39-45.
Transportation conflicts include; 1) direct habitat loss (concentrated in valley bottoms, rare productive habitats) 2) indirect habitat loss (sensory disturbance) 3) habitat fragmentation (particularly a problem in mountainous landscapes) 4) direct wildlife mortality (some species are attracted by salt, carcasses, and open travel routes) 5) public safety.

Woods, J. G. 1990. Effectiveness of fences and underpasses on the Trans-Canada Highway and their impact on ungulate populations project. Banff, Alberta: Parks Canada, Banff National Park Warden Service 103 p.

Woodward, S. M. 1990. Population density and home range characteristics of woodchucks (*Marmota monax*) at expressway interchanges. Canadian Field Naturalist. 104(3): 421-428.
Woodchucks, *Marmota monax*, were studied in 1981 at six interchanges along Highway 417 in Ottawa and Nepean, Ontario (Canada), to determine population densities and how the animals utilize this man-made habitat. The fall density of 5.36 woodchucks per hectare of a suburban interchange exceeded any density previously reported for this species in any habitat. Neither the areas nor the lengths of the home ranges of woodchucks inhabiting the suburban interchange (Richmond) and one of the urban interchanges (Pinecrest) were significantly different. Watercourses, the expressway, and associated slopes encouraged linear shapes of home ranges. Woodchucks living on flat areas and those living adjacent to ramps that they crossed exhibited non-linear home ranges. The "road-wise" woodchucks crossed single-lane on- and off-ramps frequently and successfully; wider roads were crossed infrequently.

Wu, E. 1998. Economic analysis of deer-vehicle collisions in Ohio. In: Evink, G. L.; Garrett, P.; Zeigler, D.; Berry, J., eds. Proceedings of the international conference on wildlife ecology and transportation; 1998 February 10-12; Ft. Myers, FL. Tallahassee, FL: Florida Department of Transportation: 43-52.
More than 24,000 deer-vehicle collisions (DVCs) took place in the state of Ohio in 1996, yet Ohio state agencies still hesitate to try new mitigation techniques. Ohio primarily uses deer warning signs to reduce deer-vehicle collisions because state agencies question the effectiveness and economic efficiency of other mitigation approaches. The objectives of this research are to estimate the costs and benefits of reducing DVCs. Focusing on DVCs along two stretches of highway (U.S. 33 and U.S. 50) in Athens County, Ohio, all four mitigation strategies evaluated yield positive net gains. The technique demonstrated in the research can serve as an additional decision making tool for those with responsibility for installing DVC mitigations.

Yanagawa, Hisashi; Shibuya, Tatsuo. 1996. Causes of wild bird mortality in eastern Hokkaido II. Res. Bull. Obihiro Univ. Nat. Sci. 19(4): 251-258.
The majority of wild bird mortalities in Hokkaido were caused by collisions with windows and other man-made structures. Highway mortality was the second highest cause of death.

Yanes, M.; Suarez, F. 1995. Vertebrate crossing through culverts and under roads and railways. Quercus. 12: 31-33.

Yanes, M.; Velasco, J. M.; Suarez, F. 1995. Permeability of roads and railways to vertebrates - the importance of culverts. Biological Conservation. 71(3): 217-222.
The movement of vertebrates through 17 culverts under roads and railways in central Spain was analysed over the course of an annual cycle. Passage was detected for amphibians, lizards, snakes, small mammals, rats, hedgehogs, rabbits and several species of carnivorous mammals, including *Felis sylvestris* and *Genetta genetta*. The intensity of animal movement, which varied considerably among the groups, was influenced by various factors such as the culvert dimensions, road width, height of boundary fence, the complexity of the vegetation along the route, and the presence of detritus pits at the entrance of culverts. It is concluded that adequately designed culverts can aid the conservation of vertebrate populations.

Ylaranta, T. 1995. Effect of road traffic on heavy metal concentrations of plants. Agricultural Science in Finland. 4(1): 35-48.
The concentrations of zinc, copper, lead, cadmium and nickel in spring wheat grain and straw, Italian rye grass and lettuce were studied in a two-year field experiment conducted alongside two roads with a daily traffic density of 9,500 and 5,500 vehicles each. The experimental plots were located 22, 58, and 200 meters from the roads. As controls, polyethylene pots filled with non-contaminated soil were placed in each plot. The values for the bulk deposition of lead were 50% and those for dry deposition over 50% higher in the plot 22 meters from the roadside than in the plot 200 meters from the roadside. The bulk deposition of zinc also decreased slightly with distance from the road. Cadmium depositions were low at all experimental sites. The highest values for dry deposition of lead and cadmium were recorded when the wind blew from the road in the direction of the collectors. The heavy metal concentrations varied from plant to plant but for a particular species were similar at different experimental sites. The highest zinc, cadmium and nickel concentrations were measured in lettuce. The lead concentration of wheat straw, Italian rye grass and lettuce at 22 meters from the roadside was 1.5-3 times that of the background level at 200 meters. In wheat grain, the lead concentration was very low and did not change with distance from the road. The plants took up lead mainly from air deposition. The zinc concentration of wheat grain and the nickel concentration of Italian rye grass were also high. Cadmium concentrations were low in wheat grain and straw and in rye grass. In wheat, the zinc and copper concentrations were higher and the lead and cadmium concentrations much lower in grain than in straw.

Yoshida, Motokazu; Shigetada, Suzuki; Tamao, Ono. 1994. Morphological and genetical differences in the wild populations of *Apodemus speciosus* separated by the express way. J. Fac. Agric. Shinshu Univ. 31(2): 109-124.

Youmans, Clifton. 1992. Assessment of habitat fragmentation, roads and weather on elk harvest and elk vulnerability in the upper Bitterroot Valley, Montana. Bozeman: Montana State University. 181 p. Ph.D. dissertation.

Young, K. R. 1994. Roads and the environmental degradation of tropical montane forests. Conservation Biology. 8(4): 972-976.
Roads are often a casual agent in the degradation of tropical forests; in this paper their impact is discussed for the forested, humid montane zone. Because of their steep slopes and high elevations, these forests have disturbance regimes associated with slope instability, limited resilience, and numerous species that are elevational specialists, restricted to narrow altitudinal belts. Roads often augment slope instability and fragment ranges of specialized species. Roads can allow uncontrolled extraction of natural products and landscape conversion. Improvements are needed in the design, construction, and maintenance of these roads. Also needed are studies and mitigation efforts to reduce their effects on the specialized biota of montane forests.

Zacks, J. L. 1985. An investigation of Swareflex wildlife warning reflectors, final report. Washington, DC: U.S. Department of Transportation, Federal Highway Administration; FHWA-MI-RD-85-04. 53 p.
The rise in the number of vehicle-deer accidents has increased the need for an effective means of

keeping deer off of roadways when vehicles are present. This project evaluates the effectiveness of Swareflex warning reflectors. These red reflectors are claimed to frighten deer from the highway when illuminated by headlights of a passing vehicle. They are effective, the manufacturer argues, because deer are innately afraid of red. The research was conducted in two Phases. In Phase I the spectral sensitivity of the white-tailed deer was evaluated. The purpose was to understand some basic aspects of color vision in the white-tailed deer, since the color of the reflector was argued to be the reason for its effectiveness.

Zacks, J. L. 1986. Do white-tailed deer avoid red? An evaluation of the premise underlying the design of Swareflex wildlife reflectors. Washington, DC: Transportation Research Board, National Research Council; Transportation Research Record 1075. 43 p.
Reflectors were found ineffective at influencing captive deer movement, however the results may be confounded by experimental design factors.

Zagata, M. D.; Haugen, A. O. 1974. Influence of light and weather on observability of Iowa deer. Journal of Wildlife Management. 38: 220-228.

Zangger, A. 1995. Wildlife overpasses over a motorway as connecting means for forest arthropod communities. Switzerland: Universitat Bern. 95 p. M.S. thesis.

Zelenak, J. R.; Rotella, J. J. 1997. Nest success and productivity of ferruginous hawks in northern Montana. Canadian Journal of Zoology. 75(7): 1035-1041.
In 1993 to 1994, we investigated nest success and productivity of ferruginous hawks (*Buteo regalis*) in northcentral Montana. The 171-km^2 study area contained a variety of habitats, a high density of breeding raptors, and 24 occupied ferruginous hawk territories. Only 42% of occupied nests produced fledglings. Occupied territories produced an average of 0.96 fledglings (SE = 0.19). Successful nests produced an average of 2.30 fledglings (SE = 0.21, n = 20). Lagomorphs were scarce on the area. Richardson's ground squirrels (*Spemrophilus richardsonii*) were more numerous along the edges of cropfields and roads than in grasslands. Multiple regression indicated that Ferruginous Hawk nests closer to cropfields and roads and farther from other breeding raptors produced more young than other nests. Thus, habitats altered by humans, which were not extensive (20% cultivated), apparently had higher densities of ground squirrels and thereby benefited breeding hawks. However, because our multivariate analysis was exploratory and based on a moderate sample size, our results should be interpreted cautiously and further evaluated in future studies.

Zuiderwijk, A. 1989. Amphibian and reptile tunnels in the Netherlands. In: Langton, T. E. S., ed. Amphibians and roads. Proceedings of the toad tunnel conference; 1989 January 7-8; Rendsburg, Federal Republic of Germany. Shefford, England: ACO Polymer Products Ltd.: 67-74.