Annotated Bibliography

Biotic Impacts

Wolves

Boyd, D., and D. Pletscher. 1999. Characteristics of dispersal in a colonizing wolf population in the central Rocky Mountains. Journal of Wildlife Management 63:1094-1108. *The authors studied the dispersal of wolves in Glacier National Park, Montana from 1979-1997. Wolves tended to disperse to the north toward areas of greater wolf density and less to the south, towards areas of higher rural human activity. Human-caused mortality was highest near roads.*

James, A., and S. Smith. 2000. Distribution of caribou and wolves in relation to linear corridors. Journal of Wildlife Management 64:154-159. *Investigators used telemetry to examine the distribution of caribou and wolves in northeastern Alberta. Caribou tended to avoid human-made corridors, while wolves occasionally utilized human-made corridors. Wolf predation occurred at higher rates near corridors such as roads. The authors conclude that corridors may cause increased predation.*

Mech, L. D. 1989. Wolf population survival in an area of high road density. American Midland Naturalist 121:387-389. *Mech radiocollared and studied seventy-one wolves in the Superior National Forest, Minnesota from 1969-1986. Mortality in an area with road density of .73 km/km2 was 69% but there was no human-caused mortality in a bordering roadless area. The author concludes that wolf populations can survive in an area of high road density if roadless sanctuaries are nearby.*

Mech, L.D., S. H. Fritts, G. L. Radde, and W. J. Paul. 1988. Wolf distribution and road density in Minnesota. Wildlife Society Bulletin 16:85-87. *The authors investigated road density and wolf distribution in northeastern Minnesota. Wolf populations were inversely correlated to road density. Road densities in the study area were below the previously determined threshold density by Theil (1985) of .58 km/km².*

Merrill, S. B. 2000. Road densities and gray wolf, *Canis lupus*, habitat suitability: an exception. Canadian Field Naturalist. 114:312-313. *The author reviews studies on wolf populations in relation to road density. Road density is determined to be less significant than traffic volume and human attributes. Road density alone is not an accurate variable in determining wolf habitat.*

Mladenoff, D. J., T. A. Sickley, R. G. Haight, and A. P. Wydeven. 1995. A regional landscape analysis and prediction of favorable gray wolf habitat in the northern Great Lakes region. Conservation Biology 9:279-294. *The authors studied the recolonization of wolves into northern Wisconsin, Michigan and Minnesota. Road density and land cover complexity were the most important factors in models for predicting wolf pack locations. Wolves favored areas of low road density to high road density.*

Percy, M. P. 2000. Spatial and temporal effects of roads on large carnivores in Banff National park. 14th Annual Meeting for the Society for Conservation Biology, Missoula, MT, 9-12

June. *The authors radio-collared wolves, black bears and grizzly bears in the Banff National Park region in order to study the displacement effects of roads. Wolves and non-habituated bears avoided road crossings and roadways when traffic volumes were medium to high. Bears that chose to remain along or near roadways had higher rates of habituation and mortality. The results suggest that closure of secondary roads within the park will increase habitat security and connectivity.*

Thiel, R. P. 1985. Relationship between road densities and wolf habitat suitability in Wisconsin. American Midland Naturalist 113:404-407. *Theil evaluates the relationship between rural road systems and wolf vulnerability in Wisconsin using data on original wolf populations and increasing road density between 1926 and 1960. Wolves failed to survive in areas with road densities greater than .93 mi./miles^2.*

Thurber, J. M., R. O. Peterson, T. D. Drummer, and S. A. Thomasma. 1994. Gray wolf response to refuge boundaries and roads in Alaska. Wildlife Society Bulletin 22:61-68. *The authors studied sixty-four radiocollared gray wolves in Kenai National Wildlife Refuge, Alaska. Wolves avoided frequently used roads and used infrequently visited roads as travel corridors.*

<u>Black bear</u>

Brody, A. J., and M. R. Pelton. 1989. Effects of roads on black bear movements in western North Carolina. Wildlife Society Bulletin 17: 5-10. *Brody and Pelton studied the frequency of road crossing by 17 black bears using telemetry data in Pisgah National Forest, North Carolina. Highest crossing rates occurred on abandoned roads and roads with low traffic volume were crossed more frequently than roads with higher traffic volume.*

Carr, P. C., and M. R. Pelton. 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 38:70-77. *The authors radio monitored seven adult female black bears from 1980 to 1982 in Great Smoky Mountains National Park. Bears frequently crossed low traffic roads and used neighboring habitat. The lack of road avoidance is determined to be the result of seasonal food supplies surrounding the roaded areas.*

Powell, R. A., J. W. Zimmerman, D. E. Seaman, and J. F. Gilliam. 1996. Demographic analysis of a hunted black bear population with access to a refuge. Conservation Biology 10:224-234. *The authors compared populations of sanctuary living bears to those outside of sanctuaries by using bait counts in North Carolina. Population index values from within the refuge are higher than those outside as are index values of trailside bait stations compared to roadside bait stations. They conclude that reducing human access through large sanctuaries or eliminating roads is crucial to bear populations.*

Heyden, M. V., and E. Meslow. 1999. Habitat selection by female black bears in the central cascades of Oregon. Northwest Science 73:283-294. *The authors studied the home range and landscape habitat characteristics of 14 radio-collared black bears in the central Cascades, Oregon. Bear habitat was negatively associated with roads and positively*

associated with riparian areas. Riparian areas adjacent to roads might be decreasing the amount of available habitat.

Mountain lion

Van Dyke, F.G., R.H. Brocke, and H.G. Shaw. 1986. Use of road track counts as indices of mountain lion presence. Journal of Wildlife Management 50: 102-109. *The authors radio collared mountain lions in Arizona and Utah and tracked their movements on three study sites to assess their interactions with roads. Unimproved dirt roads were crossed more frequently than improved or hard-surface roads, suggesting avoidance. Of the home ranges evaluated, 23% had hard surface roads, 58% had improved dirt roads, and 85% had unimproved dirt roads.*

Bobcat

Lovallo, M. J., and E. M. Anderson. 1996. Bobcat movements and home ranges relative to roads in Wisconsin. Wildlife Society Bulletin 24:71-76. *Lavallo and Anderson examined home range selections of bobcats in Wisconsin in relationship to roads. Within home ranges bobcats crossed paved roads less than expected. Home range selection appeared to be a function of vehicle traffic levels and road type. In general, areas less than one hundred meters from roads contained less preferred bobcat habitat than roadless areas.*

Fox

Snow, C. 1973. Habitat management series for endangered species, report no. 6: San Joaquin kit fox *Vulpes marcotis mutica*, related subspecies and the swift fox, *Vulpes velox*. U.S. Bureau of Land Management. Note 238. *The author reviews research conducted on kit foxes and cites research, which concludes that off-road vehicles are reducing available habitat for foxes.*

Pruss, S. D. 1999. Selection of natal dens by the swift fox *(Vulpes velox)* on the Canadian prairies. Canadian Journal of Zoology 77:646-652. *The occurrence of occupied and unoccupied dens were mapped and compared with landscape characteristics in southeastern Alberta and southwestern Saskatchewan, Canada. Habitat selection favored tall grassy sites on the tops of hills near roads. The authors do not propose reasons for the den site selection, but it is suspected that roads may offer unobstructed hunting areas.*

Skunks and Racoons

Dijak, W., and F. Thompson. 2000. Landscape and edge effects on the distribution of mammalian predators in Missouri. Journal of Wildlife Management 64:209-216. *The authors studied predation patterns of striped skunk, opossum and raccoons in Missouri. Scent stations were used to determine abundance of these small mammal predators in relation to landscape characteristics such as roadside edge habitat. The authors concluded that abundance and estimated predation rates may vary according to large-scale landscape characteristics, but few patterns existed between abundance and forest edges at local levels.*

Pronghorn antelope

Ockenfels, R. A., A. Alexander, C. L. Dorothy Ticer, and W. K. Carrel. 1994. Home ranges, movement patterns, and habitat selection of pronghorn in central Arizona. Arizona Game and Fish Department. Technical Report 13, Phoenix, Arizona.

Bighorn sheep

Bear, G. D., and G. W. Jones. 1973. History and distribution of bighorn sheep in Colorado. Colorado Division of Wildlife, Denver. *The report summarizes the available information on the history of big horn distribution, population, and habitat. The author concludes that the number of studies is limited, but observation-based reports linked off-road vehicles with changes in dispersal.*

Deforge, J. R. 1972. Man's invasion into the bighorn's habitat. Transactions of the Desert Bighorn Council 16:112-115. *Based on observations of a bighorn population in California, the author concludes that off-road vehicles and other human disturbance caused a bighorn herd to reduce its use of an original home range.*

DeMarchi, R. 1975. Report and recommendations of the workshop on California Bighorn Sheep. Pages 143-163 in J. B. Trefethe, editor. The wild sheep in modern North America. Boone and Crockett Club and the Winchester Press, New York, NY. *The author reviewed the objectives and strategies for the management of bighorn sheep in California. Techniques for protecting bighorn sheep include regulating off-road vehicles and managing human recreation activities.*

Graham, H. 1980. The impact of modern man. Pages 288-309 in G. Monson and L. Sumner, editors. The desert bighorn: Its life history, ecology and management. University of Arizona Press, Tucson. *The author summarized the current impacts to bighorn sheep through interviews with wildlife managers and others who have come in contact with bighorn. A number of stories recount the disturbance of bighorn by motor vehicles or hikers, but the author concluded that the effects are minimal.*

Jorgensen, P. 1974. Vehicle use at a desert bighorn watering area. Transactions of the Desert Bighorn Council 18:18-24. *Jorgensen observed desert bighorn activity at a watering hole crossed by an unimproved road in California. Bighorn activity decreased 50% on days with vehicle traffic. The researchers concluded that the bighorn were being forced to use less suitable habitat as a result of vehicle activity.*

MacArthur, R. A., R. H. Johnston, and V. Geist. 1979. Factors influencing heart rate in free-ranging bighorn sheep: a physiological approach to the study of wildlife harassment. Canada Journal of Zoology 57:2010-2021. *The investigators studied heart rates of female bighorn sheep in Alberta, Canada using telemetry. Increased activity was directly related to increases in heart rate and heart rates varied indirectly in proximity to roads.*

Penny, J. R. 1971. Off-road vehicles on the public lands in California. Pages 95-110 in M. Chubb, editor. Proceedings of the 1971 snowmobile and off the road vehicle research symposium, 14-15 June 1971. East Lansing, Michigan. Michigan State University, East

Lansing, Department of Park and Recreation. Resource Technical Report 8. *Report on the effects of off-road vehicles, including impacts to bighorn sheep and upland game birds. The author expresses some of his concerns regarding off-road vehicle impacts and sets steps for assessing the extent of their impacts.*

Rubin, W. R., W. M. Boyce, M. C. Jorgensen, S. G. Torres, C. L. Hayes, C. S. O'Brien, and D. A. Jessup. 1998. Distribution and abundance of bighorn sheep in the Peninsular Ranges, California. Wildlife Society Bulletin 26:539-551. *The authors examined population structures and past trends in abundance of bighorn sheep in the Peninsular Ranges of California. Direct observations of radiocollared animals suggested that bighorn were fragmented into eight or more groups of ewes. Boundaries between ewe groups coincided, in four cases, with paved roads, leading the authors to speculate that some fragmentation was artificial.*

<u>Deer and Elk</u>

Basile, J. V., and T. N. Lonner. 1979. Vehicle restrictions influence elk and hunter distribution in Montana. Journal of Forestry 77:155-159. *The researchers concluded that vehicle restrictions increased the ability of an area in Montana to hold elk. Areas with sparse cover but low road density held elk equally as well as areas with heavy cover and high road density.*

Burbridge, W. R., and D. J. Neff. 1976. Coconino National Forest--Arizona Game and Fish Department cooperative roads-wildlife study. Pages 44-57 in S.R. Hieb editor. Proceedings of the Elk-Logging-Roads Symposium. Moscow, Idaho. December 16-17, 1976. Forest, Wildlife and Range Experiment Station University of Idaho, Moscow, ID. *Light vehicle use did not adversely impact herds in spring and summer. Heavy traffic areas appeared to disturb herds less than slow moving vehicles on primitive non-developed roads. The closure of roads did not produce a refuge effect when take data was compared with the control.*

Cole, E., M. D. Pope, and R. G. Anthony. 1997. Effects of road management on movement and survival of Roosevelt Elk. Journal of Wildlife Management 61:1115-1126. *Limited vehicle access in 35% of the Rocky Mountain study reduced core area size and home range size of Rocky Mountain Elk. The limited access policy also increased survival rate. Results showed that limiting vehicle access reduces movement and poaching.*

Edge, W. D., and C. L. Marcum. 1991. Topography ameliorates the effects of roads and human disturbance on elk. Pages 132-137 in A.G. Christensen, L. J. Lyon, and T. N. Lonner, compilers. Proceedings of a symposium on elk vulnerability. Montana State University, Bozeman. April 10-12, 1991. Mountain Chapter of the Wildlife Society. *The authors used logistic regression analysis to determine elk response to traffic volume and topographic barriers. Elk use decreased in areas of high traffic volume and low topographic barriers.*

Gratson, M. W., and C. L. Whitman. 2000. Road closures and density and success of elk hunters in Idaho. Wildlife Society Bulletin 28:302-310. *The authors studied the effects of* *vehicular access on elk harvest rates in north central Idaho. They calculated the average hunter density and success in relation to road closures between 1992 and 1995. The results indicate that managing road access can reduce hunter densities and increase hunter success.*

Gruell, G. E., J. G. Roby, K. Becker, and R. Johnson. 1976. Gross venture cooperative elk study, June 1975-November 1975. Progress report. Bridger-Teton National Forest and Wyoming Game and Fish Department. *The authors studied the movement of elk in relation to roads in the Bridger-Teton National Forest, Wyoming. Little to no movement changes were noted during the summer when traffic volume was minimal; however, increased traffic due to hunting in the fall distributed elk further from roadways. The authors concluded that elk tended to avoid traffic on roads rather than the roads themselves.*

Livezey, 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. *Livezey radiocollared and studied sixteen female deer for almost 2.5 years. When traffic on forest roads increased during the fall hunting season deer increased road avoidance from 10-200 meters to .6-2.5 kilometers. The authors concluded that increases in traffic displaced deer and caused habitat size to decrease.*

Lyon, L., J. Bucham, and G. Milo. 1998. Tracking elk hunters with the Global Positioning System. USDA Forest Service Research Papers RMRS no. RRS-RP-3:6. *The authors used Global Positioning System units to track elk hunters. They then examined hunter behavior in relation to roads and provided hunter density data for computer models. Hunters spent a majority of their time on or near roads.*

Lyon, L. J. 1983. Road density models describing habitat effectiveness for elk. Journal of Forestry 81:592-595. *The author studied the impact of forest roads on elk. Forest roads caused an avoidance response in elk with areas of high road density being more significant than areas of low road density.*

Lyon, L. J. 1979. Habitat effectiveness for elk as influenced by roads and cover. Journal of Forestry 77:658-660. *The author studied elk pellet counts for eight years in roaded Montana habitat. Avoidance was greatest where tree density was lowest. Traffic on open roads reduced the availability of elk habitat.*

Morgantini, L. E., and R. J. Hudson. 1979. Human disturbance and habitat selection in elk. Pages 132-139 in Symposium on elk ecology and management. Laramie, WY, April 3-5, 1978. *Elk in Alberta reacted negatively to human activities such as vehicles and hunting. They moved away from open grassland transected by roads and overgrazed areas away from roads.*

Perry, C., and R. Overly. 1976. Impact of roads on big game distribution in portions of the Blue Mountains of Washington. Pages 62-68 in S.R. Hieb editor. Proceedings of the Elk-Logging-Roads Symposium. Moscow, Idaho. December 16-17, 1976. Forest, Wildlife and Range Experiment Station University of Idaho, Moscow, ID. *The authors studied the impact of roads on deer and elk in the Blue Mountains of Southeastern Washington. On main roads big game use increased 54% at .2km from the road's edge and another 54% at .4km from the roads edge. Roads in dense forest had the least effect on big game while roads in meadows had the greatest impacts. The researchers conclude that over 640 acres of elk habitat can be affected per one mile of road.*

Rost, G. R., and J. A. Bailey. 1979. Distribution of mule deer and elk in relation to roads. Journal of Wildlife Management 43: 634-641. *Rost and Bailey studied mule deer and elk responses to roads by mapping fecal-pellet groups and their varying distances from roads. They recorded pellet locations in the Roosevelt National Forest and White River National Forest, Colorado. Pellet group densities increased with distance from roads. Both deer and elk frequently avoided heavily traveled roads and roads near human habitation. The authors also examined the movement of deer and elk relative to forest roads on winter ranges. Deer and elk avoided roads, particularly within 200 meters of the roads edge. Avoidance was greatest on the most heavily traveled roads and on those with the least vegetation. Deer response was more dramatic than elk response.*

Rowland, M. M., M. J. Wisdom, and B. K. Johnson. 2000. Elk distribution and modeling in relation to roads. The Journal of Wildlife Management 64:672-684. *The authors investigated the validity of the elk-road density model for summer seasons at the Starkey Experimental Forest and Range in northeast Oregon. The model was valid suggesting that road and related human activity continue to be a disturbance factor during spring and summer.*

Sage, R. W. Jr., W. C. Tierson, and G. F. Mattfeld. 1983. White-tailed deer visibility and behavior along forest roads. The Journal of Wildlife Management 47:940-953. *The authors studied the behavior of white-tailed deer in northern New York from 1962 to 1977 and involved 4,727 observations. Few numbers of deer accounted for a majority of the roadside sightings indicating that deer behavior in relationship to roads varies according to individuals in a population.*

Sundstorm, C., and E. Norberg. 1972. A brief summary of the influence of roads on elk populations. USDA Forest Service. *Authors review a number of studies and conclude that one mile of roads per one square mile of summer elk habitat is appropriate for elk management purposes.*

Unsworth, J. W., L. Kuck and, E. O. Garton. 1998. Elk habitat selection on the Clearwater National Forest, Idaho. The Journal of Wildlife Management. 62:1255-63. *The authors studied habitat selection between sexes in the Clearwater National Forest, Idaho. Cow elk preferred shrub habitat and less open timber habit than bull elk. In roaded areas elk preferred habitat with greater canopy cover.*

Witmer, G. W., and D. S. DeCalesta. 1985. Effects of forest roads on habitat use by Roosevelt Elk. Northwest Science 59:122-125. *The authors monitored six female Roosevelt elk for one year in the central Coast Range of Oregon. Elk movements were compared to 200* *randomly chosen points surrounding roads. When compared to a narrower surrounding band significantly fewer observations were noted.*

Javelina

Day, G. I. 1971. Statewide Investigations Project: Javelina Activity Patterns. Arizona Game and Fish Department Project W-078-R-15/WP02/J09. *Arizona Game and Fish telemetered and studied the distribution of javelina in Arizona relative to humans and four-wheel drive use. The authors concluded that during winter herds were under stress from four-wheeled vehicles.*

Reptiles

Berish, J. E. D. 1998. Characterization of rattlesnake harvest in Florida. Journal of Herpetology 32:551-557. *The authors studied mortality of rattlesnakes in Florida by conducting interviews and examining 714 snakes brought to a snakeskin processing plant. Most of the interviewed individuals opportunistically killed rattlesnakes on roads, only five indicated that they actively hunted rattlesnakes. Many indicated that they would kill rattlesnakes near human habitation regardless of any potential monetary gain.*

Busack, S. D., and R. B. Bury. 1974. Some effects of off-road vehicles and sheep grazing on lizard populations in the Mojave Desert. Biological Conservation 6:179-183. *The authors investigated the effect of sheep grazing and off-road vehicle use on lizard populations in the Mojave Desert. In the study area vehicle use eliminated vegetation and adversely affected lizard populations.*

Weatherhead, P. J., and K. A. Prior. 1992. Preliminary observations of habitat use and movements of the eastern massasauga rattlesnake (*Sistrurus v. catenatus*). Journal of Herpetology 26:447-452. *The authors used radiotelemetry to monitor 12 eastern massasauga rattlesnakes within Bruce Peninsula National Park, Ontario. The snakes preferred use of wetland and coniferous habitat and avoided roads, open water and mixed forest.*

Desert tortoise

Boarman, W. I., M. Sazaki, and W. B. Jennings. 1997. The effect of roads, barrier fences, and culverts on desert tortoise populations in California, USA. Pages 54-58 in Jim Van Abbema, editor. Proceedings: conservation, restoration, and management of tortoises and turtles-an international conference July 11-16, 1993, State University of New York, Purchase, N. Y. New York Tortoise and Turtle Society & WCS Turtle Recovery Program, New York. *The authors review the effects of roads on desert tortoise populations and the effectiveness of barrier fences, culverts and road bypasses in protecting tortoises against road kills. Roads were determined to inhibit dispersal and the authors supported the use of fences and culverts as management tools.*

Bury, R. B. 1978. Desert tortoises and off-road vehicles: do they mix? Page 126 in Desert Tortoise Council Proceedings, 1978, Symposium 1-3 April 1978, Las Vegas, Nevada. Desert Tortoise Council, San Diego, CA. *Bury studied tortoise populations in the Mojave Desert to determine the relationships between off-road vehicles and distribution.*

Tortoise numbers and biomass were lower in vehicle impact areas, as were the number of burrows and the percentage of active burrows. The author concludes that off-road vehicles displace or kill tortoises, collapse burrows, and degrade habitat.

Doak, D., P. Kareiva, and B. Klepetka. 1994. Modeling population viability for the desert tortoise in the western Mojave Desert. Ecological Applications 4:446-460. *The authors studied population trends of desert tortoise using size-structured demographic models. The models correlate with field censuses and show declines in desert tortoise. The authors suggest that managing shooting, off-road vehicles and upper respiratory tract disease will best help reverse population decline.*

Luckenbach, R. A. 1982. Ecology and Management of the Desert Tortoise *Gopherus agassizzii* in California. Pages 1-37 in R. B. Bury, editor. North American Tortoises: Conservation and Ecology. U. S. Fish and Wildlife Service. Wildlife Research Report 12. *The article describes the distribution and abundance of desert tortoise and provides a review of its ecology and the factors leading to decline. Causes of decline include habitat destruction and direct mortality from off-road vehicles.*

U.S. Geological Survey. 1997. Abstracts from the 22nd annual meeting and symposium of the Desert Tortoise Council. Sam's Town Hotel, Las Vegas, Nevada. 4-6 April, 1997. U.S.G.S. BRD, California, Science Center. *The proceedings include 17 abstracts of presentations and papers on the desert tortoise. Several papers deal with the impacts of noise on desert tortoise and extinction due to recreational impacts such as ORV use.*

<u>Amphibians</u>

DeMaynadier, P. G., and M. L. Hunter, Jr. 2000. Road effects on amphibian movements in a forested landscape. Natural Areas Journal 20:56-65. *The authors compared the effects of a wide, high-traffic forest road to those of a narrow low-traffic road for eight amphibian species in Maine. Salamander abundance decreased with an increase in roads. The authors concluded that forest roads can inhibit movement and degrade habitat in some amphibian species.*

DeMaynadier, P. G., and M. L. Hunter, Jr. 1995. The relationship between forest management and amphibian ecology: a review of the North American literature. Environmental Reviews 3:230-261. *The authors studied the impact of roads on amphibians. While direct kills were considered significant, even more serious was the possible impact of roads as barriers to dispersal. Pooled water in ruts was studied as possible breeding area for amphibians but results showed that ruts were seldom used.*

Fahrig, L., J. H. Pedlar, S. E. Pope, P. D. Taylor, and J. F. Wegner. 1995. Effect of road traffic on amphibian density. Biological Conservation 73:177-182. *The authors estimated the effects of roads on frogs and toads by identifying direct kills according to varying levels of traffic. The number of live and dead frogs decreased with increasing traffic and the proportion of dead frogs and toads increased with increasing traffic. They conclude that increases in traffic volume can contribute to declines in amphibian populations and act as barriers to anuran populations.*

Gibbs, J. P. 1998. Amphibian movements in response to forest edges, roads, and streambeds in southern New England. Journal of Wildlife Management 62:584-589. *Gibbs studied amphibian dispersal relative to roads, forest edges and streambeds on a 100-ha preserve in New Haven, Connecticut. Three salamanders, two frogs and a newt were included in the study. All species had lower edge habitat capture rates than interior habitats.*

Juterbock, J. E., reviewer. 1990. Amphibians and Roads. Copeia 1:260-261. *This volume contains the proceedings of the Toad Tunnel Conference held in West Germany in 1989. The book documents many of the effects of road development on amphibians and argues that roads may determine the future of many populations.*

Seabrook, W. A., E. B. Dettman. 1996. Roads as activity corridors for cane toads in Australia. The Journal of Wildlife Management 60:363-368. *The authors studied the dispersal of the exotic cane toad in Australia. The toad used roads as corridors for dispersal and its presence altered existing native ecosystems. Road networks built into presettlement ecosystems risk dispersing cane toads.*

Vos, C. C., and J. P. Chardon. Effects of habitat fragmentation and road density on the distribution pattern of the moor frog (Rana arvalis). The Journal of Applied Ecology 35:44-56. *The authors examined the effects of habitat fragmentation on the moor frog in England. Fragmentation altered distribution and road networks caused frogs to change their selection of habitat.*

Welsh, H. and L. M. Ollivier. 1998. Stream amphibians as indicators of ecosystem stress: a case study from California's redwoods. Ecological Applications 8:1118-1132. *The authors analyzed the effect of highway construction on three amphibians. A storm during construction increased sediment causing decreases in two salamander species and a frog species as compared with a control system.*

Small mammals

Adams, L. W. and A. D. Geis. 1983. Effects of roads on small mammals. The Journal of Applied Ecology 20:403-415. *The authors studied the effects of roads on the diversity, spatial distribution, and density of small mammals. Forty species of small mammals were snap-trapped. Small mammal community structure and density were both influenced by roads.*

Bias, M., and M. Morrison. 1999. Movements and home range of salt marsh harvest mice. Southwestern Naturalist 44:348-353. *The home range and movement patterns of salt marsh harvest mice (Reithrodontomys raviventris) were studied at Mare Island Naval Shipyard, Solano Co., California. Mean home range was 2,133 square meters and was largest in June and smallest in July. Mice crossed roads, levees and canals.*

Gerlach, G., and K. Musolf. Fragmentation of landscape as a cause for genetic subdivision in bank voles. Conservation Biology 14:1066-1074. *The authors studied the barrier effects of various roadways on bank vole genetic subdivisions. Country roads and railways had* *minimal effects on population subdivisions, but paved roadways, with higher traffic volumes, had significant effects.*

Korn, H. 1992. Rapid repopulation by small mammals of an area isolated by roads. Mammalia 55:629-632. *The ability of small mammals to repopulate areas surrounded by roads was studied in Germany. Most small mammals did cross the roads and repopulate areas, but their numbers were not large enough to sustain populations.*

Oxley, D. J., M. B. Fenton and G. R. Carmody. 1974. The effects of roads on populations of small mammals. Journal of Applied Ecology 11:51-59. *Through trapping and observation roads were shown to inhibit small mammal movement. Of 433 recaptures only 14 crossed roads and none crossed roads greater than 30 meters. The study showed very little difference in crossings of paved and unpaved roads and in traffic volume.*

Reading, R. P., and R. Matchett. 1997. Attributes of black-tailed prairie dog colonies in northcentral Montana. Journal of Wildlife Management 61:664-674. *Reading and Matchett examined several characteristics of black-tailed prairie dog in Phillips County, Montana. Prairie dogs were more numerous on BLM lands than on private lands and preferred clay—loam and loam soils. No correlation was found between prairie dog density and roads, although roads are commonly used for dispersal.*

Richardson, J. H., R. F. Shore, and J. R. Treweek. 1997. Are major roads a barrier to small mammals? Journal of Zoology 243:840-846. *The authors studied the influence of road width and traffic volume on small mammal road crossing ability. Both traffic intensity and road width decreased small mammal movement.*

Swihart, R. K., and N. A. Slade. 1984. Road crossing in *Sigmodon hispidus* and *Microtus ochrogaster*. Journal of Mammalogy 65:357-360. *Swihart and Slade examined the effect of a small dirt road on prairie voles and cotton rats was in Jefferson County, Kansas. Less than 5% of the captures crossed the road and more than 80% moved away from the road.*

Wilkins, K. T. 1982. Highways as barriers to rodent dispersal. Southwestern Naturalist 27:459-460. *The authors captured and marked 1,968 rodent individuals of 10 species in order to study movement across highways. Only small percentages (less than 10%) of three species crossed roads. The authors concluded that highways acted as barriers to the species studied.*

Macroinvertebrates

Haskell, D. G. 2000. Effects of forest roads on macroinvertebrate soil fauna of the southern Appalachian Mountains. Conservation Biology 14: 57-63. *The author took forest roadside samples of soil in the southern Appalachian mountains and compared macroinvertebrate abundance and richness to control areas. Macroinvertebrates are essential in nutrient and energy processing. Roads decreased the abundance and richness of macroinvertebrates to 100 meters away from the road.*

Munguira, M. L., and J. A. Thomas. 1992. Use of road verges by butterfly and burnet populations, and the effects of roads on adult dispersal and mortality. The Journal of Applied Ecology 29:316-329. *The authors studied the type and number of butterfly species and their movement patterns across roads in Dorset and Hampshire, England. Mark-recapture methods showed that 10 – 30% of three species crossed roads. Vehicles killed .6-1.9% of closed populations and 7% of open populations. The authors concluded that roads were not a barrier to gene flow.*

Smith, M. E. and J. L. Kaster. 1983. Effect of rural highway runoff on stream benthic marcroinvertebrates. Environmental Pollution Series A, Ecological and Biological 32:157-170.

Insects

Bellinger, R. G., F. W. Ravlin, and M. L. McManus. 1989. Forest edge effects and their influence on gypsy moth egg mass distribution. Environmental Entomology 18:840-843. *The authors compared gypsy moth egg masses on forest edge and interior trees in Virginia. Edge trees, which extended 40 meters into the interior, had 2.4 times as many egg masses as interior trees.*

Roland, J. 1993. Large-scale forest fragmentation increases the duration of tent caterpillar outbreak. Oecologia 93:25-30. *Roland compares the outbreak of tent caterpillars in Ontario, Canada with historic distribution in relation to forest fragmentation. Fragmentation was based on the percentage of lands cleared, forested areas and extent of forest edge. Tent caterpillar outbreaks increased with forest fragmentation and forest edges were determined to be locations for source populations.*

Rothman, L. D. and J. Roland. 1998. Forest fragmentation and colony performance of forest tent caterpillar. Ecography 21:383-391. *The authors studied the performance of tent caterpillars on two forest sites in Alberta, Canada. As forest cover decreased and edge habitat increased tent caterpillars reproductive rates and larvae survival increased. The authors believe that tent caterpillar success is a factor of nuclear polyhedrosis virus occurrence. This virus, which attacks tent caterpillars, is shown to become inactive after 10 hours of direct sunlight exposure.*

Schowalter, T.D. and J.E. Means. 1989. Pests link site productivity to the landscape. Pages 248-250 in D. A. Perry et al., editors. Maintaining the long-term productivity of Pacific Northwest forest ecosystems. Timber Press, Portland Oregon. *Landscape patterns such as intersection by roads or other corridors, patch size, and diversity of stand age classes influence the population and diversity of pests. Pest success increases with forest simplification. When the diversity of habitats decreases, the diversity of pest predators, such as spiders and birds, declines. Similarly road intersection increases the likelihood of pests finding suitable hosts.*

Terranella, A. C., L. Ganz, and J. J. Ebersole. 1999. Western harvester ants prefer nest sites near roads and trails. Southwestern Naturalist 44:382-384. *The authors investigate the* *dispersal preferences of harvester ants on five plots near Colorado Springs Colorado. Ants preferred to disperse along disturbed corridors such as trails and roads.*

Raptors

Beaver, D., and J. Roth. 1997. Winter survey of raptors with notes on avian scavengers in northwestern Colorado. Great Basin Naturalist 57:184-186. *The authors surveyed raptors along 175 km of rural roads in northwestern Colorado. Golden eagles occurred in greater abundance during winter periods than in comparable habitat.*

Bosakowski, T., and R. Speiser. 1994. Macrohabitat selection by nesting northern goshawks: implications for managing eastern forests. Studies in Avian Biology 16:46-49. *The authors analyzed the macrohabitat data from 16 northern goshawk nest sites and 70 random sites in New York and New Jersey. The most important discriminating variables were determined to be distance from paved roads and elevation.*

Bosakowski, T., D. G. Smith, and R. Speiser. 1992. Nest sites and habitat selected by Cooper's hawks, *Accipiter cooperii*, in northern New Jersey and southeastern New York. Canadian Field-Naturalist 106:474-479. *The authors studied twenty-one cooper's hawk nest sites for habitat characteristics in a forested region of the United States. Five nests were located within 37-100 meters of roads suggesting tolerance to traffic and use of roads as open hunting areas. However, most nests occurred in deeper forests averaging 511 meters from paved roads.*

Call, M. W. 1979. Habitat management guides for birds of prey. U. S. Bureau of Land Management. Technical Report, Note 338. *The study reports on the human impacts to birds of prey. Management suggestions include locating recreational activities, such as camping and off-road vehicle use, away from nesting and roosting sites. The authors also recommend closing sensitive areas to recreation.*

Kahl, J. R. 1972. Osprey management on the Lassen National Forest. Pages 7-13 in J. Yoakum, editor. California-Nevada Wildlife. Transactions of the Annual Meeting for the Western Section of The Wildlife Society and the California-Nevada Chapter of the American Fisheries Society, 28-29 January 1972, San Luis Obispo, California. *Kahl investigates the effect of recreationists on Osprey breeding sites in Lassen National Forest. Some egg loses due to recreation activities were reported, resulting in new recreation management policies.*

Knight, R. L., and J. Y. Kawashima. 1993. Responses of raven and red-tailed hawk populations to linear right-of-ways. Journal of Wildlife Management 57:266-271. *The authors studied the abundance of common ravens and red-tailed hawks along linear corridors in the Mojave Desert, California. Ravens were found to be more common along highways than control areas and red-tailed hawks were found to be more abundant along power line corridors than control areas. The authors conclude that automobile-generated carrion and superior perch sites, respectively are the reasons behind the avian behavior.*

Meunier, F. D., C. Verheyden, and P. Jouventin. 2000. Use of roadsides by diurnal raptors in agricultural landscapes. Biological Conservation 92:291-298. *The authors compared the activity of diurnal raptors along roadsides to that of open cropland. Motorways were used more than adjacent areas by buzzards (Buteo buteo), kestrels (Falco tinnunculus) and black kites (Milvus migrans), but not by harriers (Circus, spp.). There was no correlation between use and abundance of prey. The authors speculate that roadsides provide opportunity for more optimal foraging by some raptors.*

Poulin, R. G. 1998. Male common nighthawk use of gravel roads at night. Prairie Naturalist 30:85-90. *Male nighthawks were found to rest on gravel roads at night in Saskatchewan. These nighthawks demonstrated unexpected behavior and several hypothesis for the resting, such as thermal heat regulation and clear landing area, are given.*

Zelenak, J. R. and Rotella, J. J. 1997. Nest success and productivity of Ferruginous Hawks in northern Montana. Canadian Journal of Zoology 75:1035-1041. *The authors studied nest success of ferruginous hawks in north-central Montana. Multiple regression analysis showed that ferruginous hawks nested closer to roads and human-modified edge habitat and further from other breeding bird species, which produced more young. The authors associate distribution with the abundance of squirrels which is greater near roads and edge habitat.*

<u>Owls</u>

Harding, B. D. 1986. Short-eared owl mortality on roads. British Birds 79:403-404. *The author documents his observation of 12 short-eared owl road casualties on a stretch of road near Yarmouth, England. The author can find no explanation for the unusually high number of mortalities, but suspects the deaths occurred during hunting.*

Nero, R. W. 1986. Great gray owls apparently feeding on frogs on roads at night. Blue Jay 44:189-190. *The author documents the occurrence of great gray owls preying on frogs migrating across roads at night in Manitoba, Canada. As many as 15 to 25 owls were observed along a 90 km stretch of road and several fatalities were narrowly avoided.*

Plumpton, D. and R. S. Lutz. 1993. Influence of vehicular traffic on time budgets of nesting burrowing owls. Journal of Wildlife Management 57:612-616. *The authors studied the effects of vehicular traffic on burrowing owl behavior in the Rocky Mountain Arsenal, Colorado. Burrowing owls (Speotyto cunicularia) changed behavior according to two of eight time budget criteria. Disturbance from clean up on the arsenal was concluded to be minimal.*

<u>Turkey</u>

Holbrook, H. T. and M. R. Vaughan. 1985. Influence of roads on turkey mortality. Journal of Wildlife Management 49:611-614. *The researchers studied the effect of roads on turkeys. Vehicles rarely directly resulted in turkey mortality, but high traffic adversely effected turkey populations. Vehicle disruption caused shifts in home ranges.*

Thogmartin, W. 1999. Landscape attributes and nest-site selection in Wild Turkeys. Auk 116:912-923. *The author studied 113 wild turkey nests to determine landscape characteristics of nesting sites. Turkeys tended to nest in brush habitat near roads, but all of the nest sites near roads were unsuccessful. The author suspects that edge habitats sustained large predator populations.*

Wright, G. A., and D. W. Speake. 1975. Compatibility of the eastern wild turkey with recreational activities at Land Between the Lakes, Kentucky. Proceedings Annual Conference Southeast Association of Game and Fish Commission 29:578-584. *The authors studied the effects of recreational activities on telemetered turkeys in Kentucky. Turkey avoided off-road vehicle use areas.*

<u>Other birds</u>

Boren, J. C., T. Criner, D. M. Engle, M. W. Palmer, and R. E. Masters. 1999. Land use change effects on breeding bird community composition. Journal of Range Management 52:420-430. *Investigators compared changes in avian community composition with land use, vegetation cover types, and landscape patterns in 2 rural areas. Avian composition in the low density rural population landscape was related to the amount of land in deciduous forest, land fire and herbicides. In high density rural population landscape composition was related to amount of land in deciduous forest, native grassland and changes in community composition. Roads were related to loss of neotropical migrant species and increased numbers of generalist species.*

Donovan, T., R. H. Lamberson. A. Kimber, F. R. Thompson III, and J. Faaborg. 1995. Modeling the effects of habitat fragmentation on source and sink demography of neotropical migrant birds. Conservation Biology 9:1396-1401. *Using computer modeling the authors studied the effect of fragmentation on neotropical birds of the Midwest U.S. Source and sink habitat is linked by dispersal, and population declines resulted from fragmentation of source habitat in two different scenarios.*

Foppen, R. and R. Reijnen. 1994. The effects of car traffic on breeding bird populations in woodlands: 2 Breeding dispersal of male willow warblers (*Phylloscopus trochilus*) in relation to the proximity of a highway. The Journal of Applied Ecology 31:95-101.

Goodwin, W. 1999. Yellow-billed kites and roads. Honeyguide 45:17. *The author recorded several incidents of juvenile yellow-billed kite automobile mortality. He concludes that automobile fatalities due to inexperience may be contributing to declines in population because few juveniles are surviving to adulthood.*

Graul, W. D. 1981. Population surveys of selected bird and mammal species in Colorado. Pages 84-129 in Colorado Division of Wildlife, Wildlife Research Report, January 1981, Part 1. Colorado Division of Wildlife Project FW-22-R/WP01/J03. *The authors quantify disturbance of blue heron according to type, location relative to nest and reaction to intrusion. No disturbance caused permanent nest abandonment, but herons were most active during periods of non-disturbance.*

Jones, K. B., A. C. Neale, M. S. Nash, K. H. Riitters, J. D. Wickham, R. V. O'Neill and R. D. Van Remortel. 2000. Landscape correlates of breeding bird richness across the United States mid-Atlantic region. Environmental Monitoring and Assessment 63: 159-174. *The authors evaluate landscape indicator and breeding bird data to evaluate bird richness and landscape characteristics across the mid-Atlantic region of the U. S. Birds were grouped by guild and examined for variations in grouping. Forest edge was the most important landscape attribute affecting richness. Specialist guilds were negatively associated with forest edge while generalist guilds were positively associated with forest edge.*

Keyser, A. J., G. E. Hill, and E. C. Soehren. 1997. Effects of forest fragment size, nest density, and proximity to edge on the risk of predation to ground-nesting passerine birds. Conservation Biology 12: 986-994. *The authors used artificial ground nests to compare the risk of predation relative to forest size, proximity of nests to edges, and the density of nests. They recorded variations betweens small and large predators. The results showed a negative correlation between predation rate and forest fragment size. There were no significant differences in edge predation. There was an increase in large predator activity on nests.*

Kuitunen, M., E. Rossi, and A. Stenroos. 1998. Do highways influence density of land birds? Environmental Management 22:297-302. *The authors compared land bird densities 25 meters and 200 meters away from a high volume road using two transects in central Finland. Land bird density was lower closer to the road and species that avoided the road included willow warbler (Phylloscopus trochilus) and crossbills (Loxia spp.).*

Luckenbach, R. A. 1978. An analysis of off-road vehicle use on desert avifaunas. Trans. North American Wildlife National Resource Conference 43:157-162. *A review of research showing the impacts of off-road vehicle use on desert birds. Effects on breeding populations are given.*

Marini, M. A., S. K. Robinson, and E. J. Heske. 1995. Edge effects on nest predation in the Shawnee national Forest, southern Illinois. Biological conservation 74:203-213. *The authors compared rates of predation between forest edges and interiors in the Shawnee National Forest, Illinois. Predation along forest edges was greater than interior but the reasons for possible predation were not included in testing methodology.*

Mead, C. 1997. Pathetic bundles of feathers-birds and roads. British Wildlife 8:229-232. *The author reviews data on the number of direct kills to birds by automobiles. He concludes that death by automobile may be a significant source of mortality for some bird species. Furthermore, he notes how traffic on roads has altered the composition of birds by discouraging some species and encouraging others.*

Ortega, Y. K., and D. E. Capen. 1999. Effects of forest roads on habitat quality for ovenbirds in a forested landscape. The Auk 116:937-946. *The author's studied the density of oven birds adjacent to edge habitats in relation to habitat use and reproductive success in a densely forested region of Vermont. Habitat quality was inversely related to roads. The authors* *conclude that habitat quality may be lower within 150 meters of roads and may effect reproductive success.*

Paton, P. W. C. 1994. The effect of edge on avian nest success: how strong is the evidence? Conservation Biology 8:17-26. *The author analyzed data from 14 studies, 71% of these demonstrated that breeding success decreased near forest edges. Nest predation rates were greatest within 50 m of forest edges. Nesting success of birds tended to decrease when forest cohesiveness decreased.*

Porneluzi, P. A., and J. Faaborg. 1999. Season-long fecundity, survival, and viability of ovenbirds in fragmented and unfragmented landscapes. Conservation Biology 13:1151-1161. *The authors compared the breeding success of ovenbirds between fragmented and unfragmented landscapes in Missouri. Fragmented landscapes experienced 72% cowbird parasitism as compared to 4% in unfragmented areas.*

Reijnen, R., R. Foppen, and G. Veenbaas. 1997. Disturbance by traffic of breeding birds: evaluation of the effect and considerations in planning and managing road corridors. Biodiversity and Conservation 6:567-581. *Recent studies show reduced densities of breeding birds adjacent to roads. Density can underestimate habitat quality meaning that impacts of busy roads may be more serious than initially estimated. The authors discuss methods of spatial planning that can partially mitigate these impacts.*

Reijnen, R., and R. Foppen. 1995. The effects of car traffic on breeding bird populations in woodlands: 4. Influence of population size on the reduction of density close to a highway. Journal of Applied Ecology 32:481-491. *The authors studied the effect of roads on breeding birds in low and high years of overall population size. The number of affected species and the size for all species was negatively correlated with the overall population size. The conclusion is that use of density as a response variable to roads will be highly underestimated in years with high overall population size.*

Reijnen, R., R. Foppen, and C. T. Braak. 1995. The effects of car traffic on breeding bird populations in woodlands: 3. Reduction of density in relation to the proximity of main roads. The Journal of Applied Ecology 32:187-202. *The authors studied the effect of car traffic on breeding density of birds in a deciduous and coniferous woodland in Europe. Of the 43 species studied, 26 showed evidence of reduced density adjacent to roads. Noise was determined to be the greatest cause of the reduced densities.*

Reijnen, R., and R. Foppen. 1994. The effects of car traffic on breeding bird populations in woodlands: 1. Evidence of reduced habitat quality for willow warblers (Phylloscopus trochilus) breeding close to a highway. The Journal of Applied Ecology 31 85-94. *The authors studied the effect of a high traffic flow highway on the willow warbler. Between 0 and 200 meters from the roads edge warbler density was much lower than in zones with comparable habitat. The lower density was a result of fewer adult males, while yearlings in the road edge zone were 50% than in comparable habitat. The authors conclude that younger species are displaced into the less preferred habitat zone and are consequently less successful.*

Rich, A. C., and Dobkin, D. S. 1994. Defining forest fragmentation by corridor width: the influence of narrow forest-dividing corridors on forest-nesting birds in southern New Jersey. Conservation Biology 8:1109-1121. *The authors studied the distribution of migratory birds on three different road widths. Birds had significantly reduced abundance on 16 and 23-meter corridors.*

Robinson, S. K., F. R. Thompson III, T. M. Donovan, D. R. Whitehead, and J. Faaborg. 1995. Regional forest fragmentation and the nesting success of migratory birds. Science 267:1987-1990. *The impact of forest fragmentation was studied on nine birds species in the Midwest. As forest cover decreased, nest parasitism by cowbirds increased.*

Rosenberg, K. V., J. D. Lowe, and A. A. Dhondt. 1999. Effects of forest fragmentation on breeding tanagers: a continental perspective. Conservation Biology 13:568-583. *The investigators evaluated over 1,000 tanager study sites for breeding probability according to fragmentation. Location of breeding tanagers decreased with increases in forest fragmentation for all three species studied.*

Small, M. F., and M. L. Hunter. 1988. Forest fragmentation and avian nest predation in forested landscapes. Oecologia 76:62-64. *Small and Hunter studied the size of forest fragments, use of forest borders and distance of nests from forest edge in relation to predation of nests in Maine. Predation increased directly with fragmentation and the authors suggest that predators from nearby habitats may be responsible for much of the nest predation.*

St. Clair, C. C. 2000. Comparative permeability of roads, rivers and meadows to forest birds. 14th Annual Meeting of the Society for Conservation Biology, Missoula, MT, 9-12 June 2000. *This study investigates the effect of habitat fragmentation on birds in Banff National Park, Canada. Willingness to cross roads or other barriers declined with width.*

Swensson, S. 1998. Bird kills on roads: is this mortality factor seriously underestimated? Ornis Svecica 8:183-187. *Using new methods the author estimates total annual automobile kills in Sweden to total almost ten million birds. The author concludes that automobile mortality may be significant enough to affect local populations.*

Yahner, R. H., and C. G. Mahan. 1997. Effects of logging roads on depredation of artificial ground nests in a forested landscape. Wildlife Society Bulletin 25:158-162. *The authors studied nesting predation in association to logging road width and clearcut forest edge in the Barrens Grouse Habitat Management Area in central Pennsylvania. They specifically examined the number of disturbed nests under a variety of scenarios, and conclude that predators are not using roads as hunting corridors.*

<u>Fish</u>

Alexander, G. R., and E. A. Hansen. 1986. Sand bed load in a brook trout stream. North American Journal of Fisheries Management 6:9-23. *Alexander and Hansen investigated the effects of sedimentation on population over a 15 year period in Hunt Creek, Michigan. Total number of trout decreased over a five-year period during which* *sedimentation increased. Additionally, the benthic invertebrates the trout feed upon also dropped. Population changes may have also been related to changes in habitat.*

Baxter, C. V., C. A. Frissell, and F. R. Hauer. 1999. Geomorphology, logging roads, and the distribution of bull trout spawning in a forested river basin: Implications for management and conservation. Transaction of the American Fisheries Society 128:854-867. *The authors examined the spatial and temporal distributions of bull trout populations in relation to geomorphic characteristics in the Swan Basin, Montana. Bull trout numbers were positively correlated to alluvial valley segments and negatively correlated with the density of logging roads in spawning tributary catchments. Changes in redd numbers over time were negatively correlated with catchment road density. The authors suggest that protection from roads in spawning areas is critical for bull trout population survival.*

Dunham, J. B., and B. E. Rieman. 1999. Metapopulation structure of bull trout: Influences of physical, biotic, and geometrical landscape characteristics. Ecological Applications 9:642-655. *The authors studied spatial population variation of bull trout in relation to physical, biotic and geometrical characteristics within the Boise River basin of central Idaho. They concluded that conservation of Bull trout should involve larger, less isolated and less roaded habitat.*

Eaglin, G. S., and W. A. Hubert. 1993. Effects of logging and roads on substrate and trout in streams of the Medicine Bow National Forest, Wyoming. North American Journal of Fisheries Management 13:844-846. *The authors studied the relationships between road crossings, stream sediment and trout abundance. Sediment increased in accordance to road culverts. Trout standing stocks also decreased as densities of culverts increased.*

Furniss, M. J., T. D. Roelofs, and C. S. Yee. 1991. Road construction and maintenance. Pages 297-323 in Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication 19. *The authors review research on the impacts of roads on stream habitat. Roads increase soil erosion and result in higher sedimentation of aquatic habitats. Streamflow rate and volume were altered, as was channel geometry. Sedimentation also decreased macroinvertebrate populations, the primary food source of juvenile fish.*

Harr, R. D., and R. A. Nichols. 1993. Stabilizing forest roads to help restore fish habitats: a northwest Washington example. Fisheries 18:18-22. *As part of a watershed restoration project in northwest Washington unused roads traveling through waterways were decommissioned. Decommissioning improved fish habitat and range. In contrast to unused roads not treated, decommissioned roads sustained a 50-year flood largely undamaged.*

Newcombe, C. P., and J. O. T. Jensen. 1996. Channel suspended sediment and fisheries: a synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management 16: 693-727. *The authors review 80 studies on the response of fish to increases in stream sediment. They use data from the studies to develop a model*

for fish response to suspended sediment. Responses included reduced growth rates, reduced fish density, reduced fish population size, and habitat damage.

Warren, M. V. Jr., and M. G. Pardew. 1998. Road crossings as barriers to small stream fish movement. Transactions of the American Fisheries Society 127:738-834. *Investigators used mark-recapture technique to assess the movement of 21 species of fish across four types of road crossings during spring and summer flows in west-central Arkansas. Of the four types of stream crossings, movement was lowest through culverts as compared to natural reaches. Open-box and ford crossings showed little difference in movement.*

Plants

<u>General</u>

Angold, P. G. 1997. The impact of a road upon adjacent heathland vegetation: effects on plant species composition. The Journal of Applied Ecology 34:409-417. *The authors examined the effects of roads upon heathland vegetation at a total of fourteen sites in Hampshire, UK. Roadside vegetation was altered by roads and traffic. For instance, there was enhanced growth of vascular species near roads, probably as a result of increased nitrogen oxides from exhaust systems. Effects of roads on vegetation existed up to 200 meters away from high volume wide roads.*

Davidson, E. and M. Fox. 1974. Effects of off-road motorcycle activity on Mojave Desert vegetation and soil. Madrono 22:381-412. *The authors studied off-road vehicle disturbance of pit areas and trails. Results show reductions in plant species richness and abundance, increases in shrub death and increases in soil bulk density and degree of soil compaction.*

Drayton, B., and R. B. Primack. 1996. Plant species lost in an isolated conservation area in metropolitan Boston from 1894-1993. Conservation Biology 10:30-39. *The authors compared plant inventories between 1894 and 1993 in a 400-ha park in metropolitan Boston. Of the 422 species recorded in 1894, 155 no longer exist in the park. Loss of species coincided with increases in human activity, increased numbers of trails and roads and trampling of the forest floor.*

Nelson, G. C. and D. Hellerstein. 1997. Do roads cause deforestation? Using satellite images in econometric analysis of land use. American Journal of Agricultural Economics 79:80-88. *The authors matched satellite images with geographic information on land use to produce models for future land patterns. If variables that match human influence are changed to reflect reduced impact forest areas increase in size and altered areas are reduced.*

Sharifi, M. R., A. C. Gibson, and P. W. Rundle. 1999. Phenological and physiological responses of heavily dusted creosote bush *(Larrea tridentata)* to summer irrigation in the Mojave Desert. Flora 194:369-378. *The authors studied the effects of dust collection from roads, erosion and playas on creosote bush (Larrea tridentata) in the Mojave desert, California. Water use efficiency was higher in non-dusted plants and growth rates increased for non-*

dusted plants in most conditions. However, irrigation simulating rains showed that plant recovery from dusting is high.

Soil compaction

Adams, J. A., H. B. Johnson, A. S. Endo, L. H. Stolzy, and P. G. Rowlands. 1982. Controlled experiments on soil compaction produced by off-road vehicles in the Mojave Desert, California. Journal of Applied Ecology 19:167-175. *The researchers examined the vehicle impacts of motorcycles and four-wheel drive vehicles in two soil types in the Mojave Desert, California. Soil strength decreased with minimal passes and the authors suggest this may be the reason for reductions in annual plant growth on areas with relatively small compaction.*

Froehlich, H. A., D. W. R. Miles, and R. W. Robbins. 1986. Growth of young *Pinus ponderosa* and *Pinus contorta* on compact soil in Central Washington. Forest Ecology and Management 15:285-294. *The authors compared the growth of Pinus ponderosa and Pinus contorta on roads with compacted soil to undisturbed soil. Bulk density on skid trails was 15% greater than on undisturbed trails. Regression analysis showed that volume growth was reduced by 20% in areas of compacted soil.*

Exotic species

Forcella, F., and S. J. Harvey. 1983. Eurasion weed infestation in western Montana in relation to vegetation and disturbance. Madrono 30:102-109. *The researchers surveyed exotic plant species along roadsides in western Montana. Exotic plants occurred at all elevations. In grasslands and low-montane zone (ponderosa pine) exotic weeds had invaded nondisturbed areas of native vegetation. Exotic plants were not present in undisturbed areas at higher elevations.*

Gelbard, J. L. 2000. Roads as conduits for exotic plant invasions. 14th Annual meeting of the Society for Conservation Biology, Missoula, Montana, 9-12 June. *The author studied exotic species along roads in southern Utah and eastern Nevada. Along roadsides exotic species were 250% greater than in interior habitats. Additionally, exotics occurred in greater numbers alongside paved and improved gravel roads than along unimproved forested roads, suggesting that surfacing activities and volume contribute to dispersal.*

Marcus, W. A., G. Milner, and B. Maxwell. 1998. Spotted knapweed distribution in stock camps and trails of the Selway-Bitterroot Wilderness. Great Basin Naturalist 58:156-166. *The authors review the rapid spread of spotted knapweed and its dispersal from the undercarriage of vehicles. Spotted knapweed was restricted to open canopy habitats in the Selway-Bitterroot Wilderness.*

Monsen, S. B. 1994. The competitive influences of cheatgrass *(Bromus tectorum)* on site restoration. Pages 43-50 in S. B. Monsen and S. G. Kitchen, editors. Proceedings Ecology and Management of Annual Rangelands. INT-GTR-313. USDA Forest Service, Intermountain Research Station. *The author's review of the spread of cheatgrass shows that while the species was originally reported on roadways and abandoned croplands it has now invaded shrub communities, pinyon-pine woodlands and ponderosa pine forests.*

Restoration attempts in areas inhabited by cheatgrass have proven difficult because it out competes native species.

Parendes, L. A., and J. A. Jones. 2000. Role of light availability and dispersal in exotic plant invasion along roads and streams in the H. J. Andrews Experimental Forest, Oregon. Conservation Biology 14:64-75. *Parendes and Jones surveyed exotic plant species along three different types of forest roads: high-use roads, low-use roads and abandoned roads, in the western Cascades. They compare abundance with different levels of light, disturbance, and dispersal mechanisms. Exotic species were more frequent along high-use and low-use roads than on abandoned roads.*

Stapanian, M. A., S. D. Sundberg, G. A. Baumgardner and A. Liston. 1998. Alien plant species composition and associations with anthropogenic disturbance in North American forests. Plant Ecology 139:49-62. *The authors measured exotic species on 279 plots in seven regions of the United States. Of the four areas with statistically measurable sample sizes two showed strong relationships between disturbance and the number of exotic species. While the other two areas were statistically insignificant exotic species occurred on them in the highest percentages.*

Watson, A. K., and A. J. Renney. 1974. The biology of Canadian weeds. *Centaurea diffusa* and *C. Maculosa*. Canadian Journal of Plant Science 54:687-701. *The authors summarize the research on the distribution and ecology of spotted knapweed and diffuse knapweed in Canada. Both knapweed species are reported to prefer open disturbed habitat, including roads, over shaded areas.*

Abiotic Impacts

<u>Water flow</u>

Harr, R. D., W. C. Harper, and J. T. Krygier. 1975. Changes in storm hydrographs after road building and clear-cutting in the Oregon Coast Range. Water Resources Research 11:436-444. *The authors compared six small watersheds in the Oregon Coast Range for changes in streamflow after road building, logging and slash burning. Only one watershed showed significant changes in peakflows after road construction. This basin also had the largest road system (12%).*

Jones, J. A., F. J. Swanson, B. C. Wemple, and K. U. Snyder. 2000. A perspective on road effects on hydrology, geomorphology, and disturbance patches in stream networks. Conservation Biology 14:76-85. *The authors review the research on the impact of roads on hydrologic systems. They examined peak flows (floods) and debris flow effects on vegetation and channel morphology. Road networks were connected to hydrology systems and roads influenced the frequency and magnitude of peak flows.*

Jones, J. A., and G. E. Grant. 1996. Peak flow responses to clear-cutting and roads in small and large basins, western Cascades, Oregon. Water Resources Research 32:959-974. *Jones and Grant examined the effects of logging and roads on peak discharges in watersheds of Cascades, Oregon. Watersheds with roads had earlier and higher peak discharge than* *those same watersheds prior to road construction. The authors suggest that roads increase peak discharge by altering the ratio of subsurface flows to surface flows.*

King, J. G., and L. C. Tennyson. 1984. Alteration of streamflow characteristics following road construction in north central Idaho. Water Resources research 20:1159-1163. *The authors studied the effects of logging roads prior to logging on the Nez Perce National Forest in north central Idaho. They collected daily discharges from stream mouths and compared them to pre-road data and control data. One of the watersheds showed a 25% increase in peak flows and this was attributed to the basin's abundance, location and height of roadcuts.*

Megahan, W. F. 1972. Subsurface flow interception by a logging road in mountains of Central Idaho. Pages 350-356 in S.C. Csallany, T.G. McLaughlin and W.D. Striffler, editors. Watersheds in Transition. Proceedings of a symposium on watersheds in transition. Fort Collins, Colorado. June 19-22, 1972. AWRA. Urbana, Illinois. *Megahan studied the subsurface distribution of water flow by a road in two undisturbed microwatersheds in the Idaho Batholith. Subsurface flow intercepted by the road was 7.3 times greater than surface runoff from the road alone after precipitation. Some impacts of the conversion from subsurface to surface flow include soil erosion, increased runoff volume, growth rates and alterations in species composition.*

Montgomery, D. R. 1994. Road surface drainage, channel initiation, and slope instability. Water Resources Research 30: 1925-1932. *Montgomery studied road drainage and associated channel network extension at three sites, The southern Sierra Nevada, the Oregon Coast Range and the Olympic Peninsula. Drainage area and slope were determined to be the key criteria in landslides and new channel forming.*

Tinker, D. B., C. A. C. Resor, G. P. Beauvais, K. F. Kipfueller, C. I. Fernandes, and W. L. Baker. 1998. Watershed analysis of forest fragmentation by clearcuts and roads in a Wyoming forest. Landscape Ecology 13:149-165. *The authors used remote sensing data and a Geographic Information System to compare effects of roads and clearcuts in the Bighorn National Forest. They analyzed several biotic characteristics at both the landscape and cover-class (biotic community) scale. Edge density and patch density increased as a result of clearcuts and roads. Roads appeared to have greater effects on fragmentation than clearcuts because of their even distribution across watersheds.*

Wemple, B. C., J. A. Jones, and G. E. Grant. 1996. Channel network extension by logging roads in two basins, western Cascades, Oregon. Water Resources Bulletin 32:1195-1207. *Two fifth-order basins in the Cascdes of Oregon were studied to determine the mechanism by which roads increase peak surface flows. The authors conclude that new stream channels caused by roads increased the efficiency of the surface flows and increased high flows.*

<u>Erosion and sedimentation</u>

Amaranthus, M. P., R. M. Rice, N. R. Barr, and R. R. Ziemer. 1985. Logging and forest roads related to increased debris slides in southwestern Oregon. Journal of Forestry 83:229-

233. *The authors studied mass erosion events of the Siskiyou National Forest in southwestern Oregon over a twenty-year period. Although roads occupied only 2% of the study area they were the sites for more than half of the erosion slides and 60% of the erosion volume.*

Bilby, R. E., K. Sullivan, and S. H. Duncan. 1989. The generation and fate of road-surface sediment in forested watersheds in southwestern Washington. Forest Science 35: 453-468. *The authors studied erosion of sediment from heavily used valley-bottom roads and midslope secondary roads in southern Washington. Drainage from 34% of the roads inventoried emptied directly into streams rather than on the forest floor.*

Bilby, R. E. 1985. Contributions of road surface sediment to a western Washington stream. Forest Science 31: 827-838. *Bilby examined the size of sediment run-off from a gravel road in Johnson Creek, Washington. Over the one-year study period the road contributed 20.4 metric tons of sediment to the creek. Sediment consisted of primarily fine particles and came from the road rather than roadside ditches or banks.*

Egan, A. 1999. Forest roads: where soil and water don't mix. Journal of Forestry 97:18-21. *The author analyzes simple techniques to mediate impacts of roads on water quality. Erosion mitigation processes require understanding surface mechanisms, and planning roads to avoid surface run-off.*

Elliot, W. J., D. E. Hall, and S. R. Graves. 1999. Predicting sedimentation from forest roads. Journal of Forestry 97:23-29. *The authors use the water erosion prediction project (WEPP) to predict sedimentation from forest roads in over 50,000 scenarios. They conclude that the WEPP offers a way for land managers to quickly and inexpensively estimate sediment run-off.*

Hallet, B., R. M. Iverson, B. S. Hinckley, and R. H. Webb. 1981. Physical effects of vehicular disturbances on arid landscapes. Science 212:915-917. *The authors conduct rain simulation experiments in off-road vehicle areas of the Mojave desert, California. The amount and frequency of water sheet erosion increased with vehicular use. These responses are due to decreases in soil porosity, infiltration capacity, effectiveness of surface stabilizers and hydraulic resistance to overland flow.*

McCashion, J. D., and R. M. Rice. 1983. Erosion on logging roads in northwestern California: How much is avoidable? Journal of Forestry 81: 23-26. *The authors inventoried erosion on 344 miles of roads in the Coast and Klamath Mountains, California. Roads caused 152 of the 171 major erosional events inventoried and road-related erosion increased with the slope traversed by the road.*

Reid, L. M., and T. Dunne. 1984. Sediment production from forest road surfaces. Water Resources Research 20: 1753-1761. *The authors conducted a year long study of sediment from forest roads in the Olympic Mountains, Washington. They examined three factors, traffic intensity, road gradient, and road segment length. Heavily used roads* *produced 440 tons of sediment /km/yr over the study period, compared with 3.8 tons on lightly used roads.*

Rice, R. M. 1999. Erosion on logging roads in Redwood Creek, northwestern California. Journal of the American Water Resources Association 35:1171-1182. *The authors estimated road-related erosion on 100 randomly selected plots on a road network in the Redwood Creek drainage in northwestern California. The study compared results with two previous studies conducted prior to changes in forest management. The reduction of culverts and changes in their placing and sizing are decreased soil run-off.*

Rummer, B., B. Stokes, and G. Lockaby. Sedimentation associated with forest road surfacing in a bottomland hardwood ecosystem. Forest Ecology and Management 90: 195-200. *Four different surfaces, native soil, native soil with vegetative stabilization, 6 cm of gravel and 15 cm of gravel, were compared for differences in sediment runoff in the southern United States. In the first year of the study no statistical variation existed. All road surfaces released sediment. However, while not statistically significant, the 6 cm graveled surface released the greatest amount.*

Ryan, S. E., and G. E. Grant. 1991. Downstream effects of timber harvesting on channel morphology in Elk River Basin, Oregon. Journal of Environmental Quality 20:60-72. *The authors used aerial photos to evaluate the effects of forest road construction and logging in the Siskiyou National Forest, Oregon. They constructed a disturbance history from previous photos that showed an increase in first and second-order tributary open riparian canopies. In some cases, upslope activity was linked to downstream erosional changes that disrupted riparian vegetation.*

Swanson, F. J., and J. L. Clayton, W. F. Megahan and G. Bush. 1989. Erosional processes and long-term site productivity. Pages 67-81 in D. A. Perry, R. Meurisse, B. Thomas, R. Miller, J. Boyle, J. Means, C.R. Perry, R. F. Powers, editors. Maintaining the Long-Term Productivity of Pacific Northwest Forest Ecosystems. Timber Press, Portland, Oregon. *The authors review various soil erosion processes and their impact on site productivity in the Pacific Northwest. The impacts of forest roads on site productivity through erosion was variable. Downslope and upslope plant and animal species were determined to be affected by the changes in groundwater systems caused by roads.*

Swift Jr., L. W. 1984. Soil losses from roadbeds and cut and fill slopes in the Southern Appalachian Mountains. Southern Journal of Applied Forestry 8:209-216. *The effects of soil erosion by roads was studied on a timber sale access road in the southern Appalachian Mountains. Soil erosion rates increased on steeper grade test sites. Mitigation efforts significantly decreased soil erosion, but these rates remained 20 times higher than those in undisturbed forest areas.*

Taylor, S. E., R. B. Rummer, and K. H. Yoo. 1999. What we know and don't know about water quality at stream crossings. Journal of Forestry 97:12-17. *The authors provide a literature review on the sedimentation of streams at crossings. They suggest that data needs to be gathered on a wide variety of stream sizes, soil types, terrain, and*

climatological conditions so that policymakers can develop scientifically informed management. They conclude that the best way to preserve water quality at crossings is with temporary bridges.

General Reviews

<u>Biological effects of roads</u>

Findlay, C. S., and J. Bourdages. 2000. Response time of wetland biodiversity to road construction on adjacent lands. Conservation Biology. 14:86-94. *The authors examined the richness of plant, bird, amphibian, and reptile species on lands adjacent to road construction. Using multiple regression models the authors assessed the variations in species due to roads. Animal species loss was detectable within eight years while changes in plant populations were not detectable until after several decades.*

Findlay, C. S., and J. Houlahan. 1997. Anthropogenic correlates of species richness in southeastern Ontario wetlands. Conservation Biology 11:1000-1009. *The authors studied the relationship between four different wetland taxa (birds, mammals, herptiles, and plants) in 30 wetlands of southeastern Ontario and 2 disturbance factors: road construction and forest removal. Multiple regression analysis was used to model the relationships between species richness, wetland area, road density and forest cover. All taxa except mammals showed a negative correlation between density of paved roads located within 2 kilometers of wetlands.*

Foreman, R. T. T. 2000. Estimate of the area affected ecologically by the road system in the United States. Conservation Biology. 14:31-46. *Research on the physical extent of road impacts is termed the "road-effect zone" and varies according to factors such as the type of road, level of use and type of affect. Foreman estimates that the total proportion of the U.S. ecologically impacted by roads is roughly 20%, while roads themselves cover 1% of all U.S. lands. In the process Foreman evaluates two studies on assessing road-effects zones.*

Foreman, R. T. T., and L. E. Alexander. 1998. Roads and their major ecological effects. Annual Reviews of Ecology and Systematics 29: 207-231. *The authors analyze the impacts of roads on plant and animal populations. Roads change plant community composition by favoring disturbance-tolerant plants and introducing exotic species. Roads affect animal populations by displacing animals, creating barriers and causing direct fatalities. Aquatic system impacts include altered runoff patterns, increased sediment, and pollution runoff. The author's conclude that the ecological effect of roads extend geographically beyond the road itself.*

Henjum, M. 1996. Maintaining ecological integrity of inland forest ecosystems in Oregon and Washington. Wildlife Society Bulletin. 24:227-232. *A panel of members from the Eastside Forests Scientific Society Panel concludes that public land use policy has resulted in simplification of forest ecosystem and declining habitat quality for wildlife. Mining, timber harvesting and increasing road networks are some causes for biological decline.*

Markham, D. 1996. The significance of secondary effects from roads and road transport on nature conservation. English Nature Research Reports 178:1-91. *The document consists of a compilation of the secondary effects of roads, mitigation possibilities and research gaps. The author identifies nine categories of impacts: 1) air pollution; 2) noise disturbance; 3) artificial lighting; 4) aquatic impacts; 5) fragmentation and species movement; 6) wildlife casualties; 7) litter; 8) roadside verge management; 9) other effects.*

Trombulak, S.C., and C. A. Frissell. 2000. The ecological effects of roads on terrestrial and aquatic communities: a review. Conservation Biology 14:18-30. *The authors identify seven general effects of roads: 1) road construction resulted in the death of plants and slow-moving animals, compacted soils and effected water bodies at crossings; 2) roadkill effected the demography of animal species; 3) roads modified animal behavior causing species displacement, altered reproductive rates and new movement patterns; 4) roads disrupted physical geography by changing soil density, increasing surface runoff and increasing sedimentation. Hydrology was effected by changes in stream channels, slope and barriers to movement of fish and other aquatic animals; 5) pollutants from roads effected plant and animal communities through runoff; 6) roads promoted the spread of exotic species; 7) roads increased the presence of humans and human ecological impacts.*

Wisdom, M. J., V. A. Saab, D. C. Lee, W. J. Hann, T. D. Rich, M. M. Rowland, W. J. Murphy, M. R. Eames, and R. S. Holthausen. 2000. Source habitats for terrestrial vertebrates of focus in the Interior Columbia Basin: Broadscale trends and management implications. USDA Forest Service-Research Notes RMRS no. PNW—GTR-485:425-529. *The authors analyzed habitat conservation opportunities for the management of old-growth forest and rangeland in Washington. Seventy percent of the 91 species are affected negatively by one or more factors associated with roads. Additionally, roads may limit the persistence of large carnivores. Managing road networks for wildlife would require reducing the density of existing roads.*

<u>Biological effects of off-road vehicles</u>

American Association for the Advancement of Science, Committee on Arid Lands. 1974. Off-road vehicle use. Science 184:500-501. *Review of impacts of off-road vehicles on desert lands. Discusses problems associated with management and provides recommendations for future management.*

Berry, K. H. 1980. The effects of four-wheeled vehicles on biological resources. Pages 231-233 in R. L. Andrews and P. F. Nowak, editors. Off-road vehicle use: a management challenge. Conference Proceedings 16-18 March 1980, Ann Arbor, Michigan. *A summary of the impacts of vehicle use on undeveloped forest roads, including impacts on wildlife as a result of vegetation and soil changes. Also included is a discussion of management problems related to off-road vehicle resource degradation.*

Bury, R. B. 1980. What we know and do not know about off-road vehicle impacts on wildlife. Pages 110-112 in R. L. Andrews and P. F. Nowak, editors. Off-road vehicle use: a management challenge. Conference Proceedings 16-18 March 1980, Ann Arbor, Michigan. *Bury reviews the scientific knowledge of vehicle impacts in wild lands and current management strategies.*

Bury, R. B., R. A. Luckenbach, and S. D. Busack. 1977. Effects of off-road vehicles on vertebrates in the California Desert. U. S. Fish and Wildlife Service. Wildlife Res. Report 8. *The authors studied the impacts of off-road vehicles on creosote shrub habitat and associated wildlife were studied. Richness, density and biomass of birds, reptiles, and small mammals decreased as vehicle use levels increased.*

Hoover, B. 1973. Off-road vehicle problems on federal lands. Pages 37-49 in proceedings of the annual meeting: Association of the Midwest Fish and Wildlife Committee. *The article discusses the impacts of off-road vehicles including damage to wildlife habitat, direct impacts to wildlife and inadvertent harassment of animals.*

Lovich, J. E., and D. Bainbridge. 1999. Anthropogenic degradation of the southern California desert ecosystem and prospects for natural recovery and restoration. Environmental Management 24:309-326. *The authors describe the anthropogenic changes to the Mojave Desert, California, including the impacts of off-road vehicles and roads. They estimate recovery time periods from 50 to 300 years, depending on the severity and type of disruption.*

Mace, R. U. 1974. Application of vehicle restrictions in wildlife management. Proceedings of the Annual Conference of the West Association. CA State Game and Fish Commission. 54: 205-210. *The article reviews problems associated with increasing use of remote areas by off-road vehicles. It includes harassment impacts and physical destruction of habitat. Discusses difficulties of enforcement and regulation.*

McReynolds, H. E., and R. E. Radtke. 1978. The impact of the motorized human on the wildlife of forested lands. Pages 102-117 in C. M. Kirkpatrick, editor. Wildlife and People. Proceedings of the 1978 John S. Wright Forestry Conference, 23-24 February 1978, Purdue University, West Lafayette, Ind. *This is a review of the effects of off-road vehicles on wildlife. The article presents cases for and against various motorized recreation. The author concludes that few reliable studies on impacts have been conducted but it is probable that indirect effects have produced the greatest impacts.*

Sheridan, D. 1979. Off-road vehicles on public land. Council on Environmental Quality, Washington, D.C. *Notes from the conference meeting on environmental quality. The council cites several examples of impacts, examines federal policies regarding off-road vehicles, and recommends management options.*

Sheridan, D. 1978. Dirt motorbikes and dune buggies threaten deserts. Smithsonian 9:65-75. *This study indicates that in lightly used ORV desert areas plant life declined 50% while terrestrial animal life declined 60%. In areas where ORV's congregate plant life was reduced 90% and animal life was reduced 75%. Includes information on impacts to rodents.*

Stebbins, R. C. 1974. Off-road vehicles and fragile desert. American Biological Teacher. 36:203-208, 294-304. *Off-road vehicles caused the collapse of burrows, soil compaction, and depletion of forage in otherwise inaccessible areas.*

Fragmentation

Lode, T. 2000. Effect of a motorway on mortality and isolation of wildlife populations. Ambio 29:163-166. *The author studied road kills and the impact on wildlife population isolation. Over 2000 kills of 97 species occurred over a 7.5 month period on a 68 kilometer stretch of road. The results show that demography and populations are significantly affected by high flow traffic.*

Mader, H. J. 1984. Animal habitat isolation by roads and agricultural fields. Biological Conservation 29: 81-96. *Mader studied animal habitat isolation by roads and agricultural fields and animal movement. Animals in isolated areas continued to attempt movement across corridors resulting in unstable species composition.*

Reed, R. A., J. Johnson-Barnard, and W. L. Baker. 1996. Contribution of roads to forest fragmentation in the Rocky Mountains. Conservation Biology 10:1098-1106. *The authors quantified the fragmentation by forest roads in a 30,123 ha area of the Medicine Bow-Routt National Forest, Wyoming. A Geographical Information System was used to analyze several indices of landscape structure. The authors calculated that roads affect 2.5 to 3.5 times more landscape than the area occupied by the roads themselves.*

Tinker, D. B., C. A. C. Resor, G. P. Beauvais, K. F. Kipfmueller, C. I. Fernandes, and W. L. Baker. 1998. Watershed analysis of forest fragmentation by clearcuts and roads in a Wyoming forest. Landscape Ecology 13: 149-165. *The authors used remote sensing and G.I.S. techniques to compare the effects of clearcutting and road-building in north-central Wyoming. Roads appeared to be result in more changes than clearcuts, and roads that were evenly distributed across a watershed had greater effects on landscape patterns than those that were densely clustered.*

Noise disturbance

Foreman, R. T., and R. Deblinger. 2000. The Ecological Road-Effect Zone of a Massachusetts (U.S.A.) Suburban Highway. Conservation Biology 14:36-46. *The authors examined the zone over which ecological effects extended outward from a four-lane highway west of Boston, Massachusetts. Of the nine ecological factors studied all extended a distance greater than 100 meters from the road and some effects, such as noise, extended more than one kilometer.*

U. S. Environmental Protection Agency. 1971. Effects of noise on wildlife and other animals. U. S. Environmental Protection Agency, Off Noise Abate. Control NTID300.5. *This report examines the observed and suspected impacts of noise on wildlife. Observed effects include damage to hearing systems which then may impede communication and alter home ranges. Suspected impacts include damage to ear drums and alterations of communication systems.*

Pollution

Andral, M. C., S. Roger, and V. M. Montrejaud. 1999. Particle size distribution and hydrodynamic characteristics of solid matter carried by runoff from motorways. Water Environment Research 71:398-407. *This study investigated the particle size of pollution runoff during eight storm events on a section of highway in France. Over 75% of total particle mass are small enough that they remain suspended in runoff making separation difficult.*

Boxall, A. B. A. and, L. Maltby. 1997. The effects of motorway runoff on freshwater ecosystems: 3. Toxicant confirmation. Archives of Environmental Contamination and Toxicology 33:9-16. *The authors studied the content of poclyclic aromatic hydrocarbons(PAH) in sediment run-off from roads to determine if PAHs were major toxicants. PAHs accounted for anywhere between 30.8% and 120% of an extract's toxicity.*

Hares, R. J., and N. I. Ward. 2000. Effects of water pollution from roads. International Conference on Heavy Metals in the Environment, Ann Arbor, Michigan, 6-10 August 2000. *Hares and Ward measure the ability of two biofiltration balancing pond facilities to remove heavy metals from roadway stormwater was measured in England. The study showed that a "well established" reed bed and long residence time might be most effective at removing heavy metals from stormwater.*

1998. Trench captures highway runoff metals. Environmental Science and Technology 32:175. *The article provides information on a range of the pollutants distributed to streams and soils through vehicles on roads. To deal with the problem a group of Cincinnati researchers has developed a roadside filtration system.*

Literature reviews

Spellerberg, I. F. 1998. Ecological effects of roads and traffic: a literature review. Global ecology and Biogeography Letters 7:317-333. *The review of journal articles and government reports on the impacts of roads leads the author to believe that most research is focusing on methods of mitigation and few reports have assessed the ecological impacts. Research gaps include the effects of heavy metal accumulation and the effects of habitat fragmentation.*

Management strategies

Lugo, A. E., and H. Gucinski. 2000. Function, effects and management of forest roads. Forest Ecology and Management 133:249-262. *The authors suggest a unified approach to the management and analysis of roads. Approaching roads as ecosystems and conducting analyses of road ecology prior to making policy can be advantageous in terms of providing a holistic approach. The authors present five precautions to consider in road management, including the avoidance of prejudging human-induced changes as good or bad for the ecology or economy of a region.*

Swift, L. W. Jr., and Burns, R. G. 1999. The three Rs of roads: redesign, reconstruction, and restoration. Journal of Forestry 97:40-44. *The authors analyze a road system in the Apalachians for proximity to waterways and opportunities for redesign. The authors identified several affordable techniques to mitigate sediment influx in waterways.*

Public attitudes and perceptions

Adams, J. 2000. Seeds of Change. Amicus Journal 21:2. *This article from the Natural Resource Defense Council outlines philosophical changes that could result from the Roadless Initiative.*

Baker, B. 1998. Rethinking roads in the nation's forests. BioScience 48:156. *The author provides a summary of new legislative initiatives to limit road building and reduce road maintenance and repair budgets.*

Bengston, D. N., and D. P. Fan. 1999. Roads on the U. S. National Forests. An analysis of public attitudes, beliefs, and values expressed in the news media. Environment and Behavior 31:514-539. *More than 4,000 on-line news stories were analyzed using computer methods for content, values and attitudes. The concept of forest roads providing access for recreation was the most expressed belief followed by the belief that roads cause ecological damage.*

Bengston, D. N., and D. P. Fan. 1999. The public debate about roads on the national forests: an analysis of the new media, 1994-1998. Journal of Forestry 97:4-10. *This is an abbreviated version of the article published in Environment and Behavior. The authors categorize the occurrence of eight main beliefs regarding forest roads in 500 randomly selected news stories.*

Bird, B. M. 1999. A second life for dead trees: roads, fragmentation, and the loss of wildlife habitat in northern New Mexico. Wild Earth 9:79-82. *The article describes the effects of roads in the Sangre de Cristo Mountains. Activist groups have conducted fieldwork that measures road densities and the effectiveness of road closures. Densities are above recommended wildlife densities and many closures and ineffective.*

Havlick, D., and B. Walder. 1996. Road Report5. Wild Earth 6:21-22. *The organization ROAD-RIP has been working to organize citizen conducted road inventories. Data from inventories is used to propose road densities for road sensitive species and has been used in several forest planning processes.*

Scarborough, K., and K. Klungness. 1994. Developing road scholars. Wild Earth 4:133-135.

Annotated bibliographies

Albrecht, J., and D. Smith. 1977. Environmental effects of off-road vehicles: A selected bibliography of publications in the University of Minnesota Forestry Library. University Minnesota, St. Paul Campus Libraries, Forestry Library Bibliography. Series 2.

Bury, R. L., R. C. Wendling, and S. F. McCool. 1976. Off-road recreation vehicles, a research summary, 1969-1975. Texas Agriculture Experimental Station. College Station, Texas, Texas A&M University. *Compilation of articles on the effects of ORV's on wildlife. Includes snowmobile impacts and ORV effects on desert animals.*

Hieb, S. R. 1976. Proceedings of the Elk-Logging Roads symposium, Moscow, Idaho. Wildlife and Range Experimental Station, University of Idaho, Moscow. *Includes papers from a symposium on the effects of logging and roads on elk in the Western U.S.*

Lodico, N. J. 1973. Environmental effects of off-road vehicles: A review of the literature. U. S. Department of the Interior. Series 29. *A bibliography of 103 citations on the ecological effects of snowmobiles, motorcycles, all-terrain vehicles and four-wheeled vehicles.*

Luckenbach, R. A., and R. B. Bury. 1980. Off-road vehicle impact on desert vertebrates: A review. In K. Berry, editor. The physical, biological, and social impacts of off-road vehicles on the California desert. Special Publication Southern California Academy of Science. *Reviews the effects of ORV's on animals groups*.

Neil, P. H., R. W. Hoffman, and R. B. Gill. 1975. Effects of harassment on wild animals-an annotated bibliography of selected references. Colorado Division of Wildlife Special Re-publication. *Selected references on the impacts to wildlife by ORV's, roads and other human activities.*

Webb, R. H., and H. G. Wilshire. 1978. A bibliography on the effects of off-road vehicles on the environment. U.S. Geological Survey. Open-file Rep. 78-149.

Williams, M., and A. Lester. 1996. Annotated Bibliography of OHV and other recreational impacts to wildlife. USDA Forest Service Pac. SW. Reg. *The bibliography contains 54 cited references on outdoor vehicle and recreation impacts on wildlife.*

Indirect Impacts Associated with Roads and Vehicles

<u>Game poaching</u>

Bancroft, D. C. 1990. Use of wildlife enforcement decoys for wildlife enforcement in northern Arizona: preliminary results. Pages ? in P. R. Krausman and N. S. Smith editors. Proceedings of managing wildlife in the Southwest. Tucson, AZ. October 1990. University of Arizona. Tucson, Arizona. *Use of decoy elk and deer revealed widespread use of roadside hunting. Eleven of 19 archery hunters committed a violation after observing a decoy. Forty-one of 53 firearms hunters attempted illegal take after observing a decoy from their vehicles. Hunter behavior included shooting from maintained roads, shooting from vehicles, take without permit and take at night.*

Jones, S., and B. K. Barsch. Arizona Game and Fish Department Files. Region II, Flagstaff, AZ. *The researchers used turkey decoys in the White Mountains and Flagstaff area to determine the number and type of turkey hunting violations. From a sample size of 45 eighteen violations occurred. In a later study seven of twelve turkey hunters illegally* *shot from the road or from their vehicles. The researchers concluded that high road density through prime turkey habitat may contribute to turkey mortality.*

<u>Animal harassment</u>

Andersen, D. E., O. J. Rongstad, and W. R. Mytton. 1990. Home range changes in raptors exposed to increased human activity levels in southeastern Colorado. Wildlife Society Bulletin 18:1334-142. *Using telemetry the authors studied changes in home ranges in raptors exposed to military training in southeastern Colorado. Red-tailed hawks changed their home ranges drastically compared to control groups and one Swainson's hawk and ferruginous hawk abandoned their original home range altogether.*

Bart, J. 1977. Impact of human visitations on avian nesting success. Living Bird 16:187-192. *The authors studied the occurrence of increased predation following bird observance by humans. During the laying period the author detected a clear increase in mortality in four of five species studied.*

Buehler, D. A., T. J. Mersmann, J. D. Fraser, and J. I. D. Seeger. 1991. Effects of human activity on bald eagle distribution on the northern Chesapeake Bay. Journal of Wildlife Management 55:282-290. *The authors studied the relationship between human activity and bald eagle distribution on the northern Chesapeake Bay shoreline, Wisconsin. Few eagles used areas with shoreline activity, such as boats.*

Light, J. T. R. 1971. An ecological view of bighorn habitat on Mount San Antonio. Transactions from the North America Wild Sheep Conference. 1:150-157. *The author studied the effects of human interaction with bighorn sheep. Human use was shown to decrease bighorn habitat. Bighorns tolerated only limited human disturbance before abandoning home ranges.*

<u>Exotic species</u>

Lacey, J. R., C. B. Marlow, and J. R. Lane. 1989. Influence of spotted knapweed (*Centaurea maculosa*), on surface runoff and sediment yield. Weed Technology 3:627-631. *The authors compared sediment runoff on 12 paired plots of spotted knapweed and native bunchgrass. Knapweed plots experienced lower infiltration rates, higher surface runoff and greater sediment yield. Slope was identified as a highly significant variable in sediment yield.*

Randall, J. M. and M. Rejmanek. 1993. Interference of bull thistle *Cirsium vulgare* with growth of ponderosa pine seedlings in a forest plantation. Canadian Journal of Forest Research 23:1507-1513. *In the absence of other vegetation bull thistle suppressed the growth of ponderosa pine seedlings in a western Sierra Nevada plantation. Bull thistle growing within 2 meters of ponderosa pine seedlings decreased growth rate in accordance to density.*

Wicklow-Howard, M. C. 1994. Mycorrhizal ecology of shrub-steppe habitat. Pages 207-210 in S. B. Monsen and S. G. Kitchen, editors. Proceedings - Ecology and Management of Annual Rangelands. INT-GTR-313. USDA Forest Service. Intermountain Research

Station. *The author reviews the occurrence of mycorrhizal fungi on native and non-native plants in shrub-steppe habitat of southwestern Idaho. Ninety-nine percent of native plants on undisturbed sites were mycorrhizal, while 1% of successful exotics were mycorrhizal. The long-term effects of mycorrhizae occurrence on succession are discussed.*

Woods, K. D. 1993. Effects of invasion by *Lonicera tatarica* on herbs and tree seedlings in four New England forests. American Midland Naturalist 130:62-74. *Woods examined the occurrence of Lonicera tatarica, exotic honeysuckle, in four stands of southwestern Vermont and northwestern Massachusetts. Honeysuckle altered community composition and dynamics on three of the four plots. It decreased the number and richness of herbaceous species and the density of tree seedlings.*

<u>Soil compaction</u>

Amaranthus, M. P., D. Page-Dumroese, A. Harvey, E. Cazares, and L. F. Bednar. 1996. Soil compaction and organic matter affect conifer seedling nonmycorrhizal and ectomycorrhizal root tip abundance and diversity. Research Paper PNW-RP-494. USDA Forest Service. Pacific Northwest Research Station. *The authors studied the effects of removal of organic matter and soil compaction on ectomycorrhizal occurrence on Douglas-fir and western white pine seedlings. Ectomycorrhizal abundance decreased 60% and diversity decreased from 2.7 to 1 on highly compacted sites.*

Childs, S. W., S. P. Shade, D. W. R. Miles, E. Shepard, and H. A. Froehlich. 1989. Soil physical properties: importance to long-term forest productivity. Pages 53-66 in Maintaining the long-term productivity of pacific northwest forest ecosystems. D. A. Perry et al., editors. Timber Press, Portland, Oregon. *The authors review the consequences of soil compaction. Compaction decreases soil aeration, decreases water storage and increases bulk density. Reductions in root growth and a plant ability to access nutrients are also results of soil compaction. Mycorrhizal fungi abundance is reduced by compaction, as is infiltration rate and site productivity. Studies show that soil compaction impacts can last several decades.*

<u>Mychorrhizae and soil organisms</u>

Amaranthus, M. P., and D. A. Perry. 1994. The functioning of ectomycorrhizal fungi in the field: linkages in space and time. Plant and Soil 159:133-140. *The authors review the importance of ectomycorrhizal fungi to the growth and survival of trees. Benefits to trees include increased nutrient and water uptake, protection against pathogens and maintenance of soil structure.*

Marshner, H., and B. Dell. 1994. Nutrient uptake in mycorrhizal symbiosis. Plant and Soil 159:89-102. *The authors review the research on mycorrhizae nutrient uptake. Mycorrhizae can increase nutrient uptake by increasing the surface absorbing area, modifying soil microflora and excreting beneficial compounds.*

Amaranthus, M. P., J. M. Trappe, and R. J. Molina. 1989. Long-term forest productivity and the living soil. Pages 36-52 in D. A. Perry et al., editors. Maintaining the long-term

productivity of Pacific Northwest Forest Ecosystems. Timber Press, Portland, Oregon.
The authors review the research on upper soil layers and their significance in soil nutrient cycling. Soil organisms are largely concentrated in organic layers and are critical for nutrient cycling, including processes such as decomposition, nutrient storage, and nitrogen fixing. Soil compaction and soil erosion greatly reduce organic soil layers.

Sedimentation and aquatic insects

Brusven, M. A., and K. V. Prather. 1974. Influence of stream sediments on distribution of marcrobenthos. Journal of the Entomological Society of British Columbia 71:25-32.
Aquatic insects in the orders of Ephemeroptera, Plecoptera, Trichoptera, and Diptera were studied in the laboratory and in natural habitat to determine their streambed preference. All five species preferred exposed cobble as opposed to sediment laden surface in artificial habitats and four of the five preferred exposed cobble in natural waterways.

Jackson, J. K., and V. H. Resh. 1989. Distribution and abundance of adult aquatic insects in the forest adjacent to a northern California stream. Environmental Entomology 18:278-283.
The authors surveyed the distribution of adult aquatic insects in forests adjacent to streams in northern California. At distances up to 40 meters of the stream aquatic insects represented 30% of the species composition and 25% of the biomass. Abundance and biomass decreased with distance from the stream but estimated roughly 10% at 150 meters from the stream. The authors conclude that insects are an important link between aquatic and terrestrial habitats and that they are an important part of the food web for forest animals.

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