EXHIBIT 22

David G. Havlick, *No Place Distant* (Island Press 2002) (excerpts)

No Place Distant

Roads and Motorized Recreation on America's Public Lands

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ISLAND PRESS
Washington • Covelo • London

Library of Congress Cataloging-in-Publication Data
Havlick, David G.
No place distant : roads and motorized recreation on America's public
lands / David G. Havlick.
p. cm.
Includes bibliographical references (p.) and index.
ISBN 1-55963-844-3 — ISBN 1-55963-845-1 (pbk.)
1. Public land roads—United States. I. Title.
HE336.P82 H38 2002
388.1'2—dc21 2001006979

British Cataloguing-in-Publication data also available.

Printed on recycled, acid-free paper.

Manufactured in the United States of America
09 08 07 06 05 04 03 02 8 7 6 5 4 3 2 1

Contents

Roads are daggers thrust into
the heart of nature.

—Michael Soulé, 2000

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For much of history, science and roads met only in the context of how we could apply knowledge of engineering, chemistry, and geology toward building better, longer-lasting, smoother, cheaper, and safer roads. In many places, road construction continues to be the primary focus of science upon roads. In recent decades, however, ecologists, conservation biologists, and others have come to roads posing new types of questions. How do roads affect long-term natural processes in landscapes or watersheds? What impacts do roads have upon plant and animal species, populations, communities, or ecosystems? How do roads combine with various uses of roads—such as logging, hunting, or driving a motor vehicle—in ways that lead to new and different consequences?

By working to answer these questions and examining the ecological effects of roads, we can better determine our priorities for future road management. Using effective outreach and education, land managers may find it increasingly feasible to remove or limit roads where they present significant ecological hazards and provide comparatively little access or public benefit. Even where the decisions are more difficult, for example when a popular road carries major ecological liabilities, a thorough understanding of road impacts will help us evaluate long-term management priorities. This knowledge—the *scientia* of roads—provides a critical link in evaluating and determining the future of roads and motorized access on public lands.

The ecological effects of roads can be lumped broadly into two categories: use effects and presence effects. Use effects, or impacts caused by human activities on roads, include some of the more commonly noticed effects from roads such as animals killed by collisions with vehicles (roadkill), road-based logging or mining operations, increased access for hunting and fishing, and the transport and dispersal of exotic plants. Presence effects, those impacts triggered simply by the existence of the road on the landscape, can be both subtle and long lasting. On land they generate erosion, habitat fragmentation and loss, soil compaction, and increased edge habitat. Aquatic impacts range from increasing sedimentation to changing the way water moves through the landscape.

These two categories—use effects and presence effects—prove helpful for a broad conceptual framework, even if they do not offer a perfect fit for every ecological consequence of roads. On occasion, the categories overlap. For example, erosion occurs both from the use of a road and from its mere presence on the land. Similarly, invasive weeds enter roaded areas both from active human transport and by wind, water, or wildlife dispersal in the road corridor. Ecological effects might also be classified usefully into categories such as aquatic and terrestrial, intentional and inadvertent, or direct and indirect. But for our purposes here, classifying road impacts by use effects and presence effects is the most appropriate because that division links the ecological consequences of roads most clearly to their causes. This can, in turn, help guide managers and citizens to address road-related problems.

Like most forms of technology, roads come with both negative and positive effects. Historically, we have emphasized the socially or economically beneficial aspects of roads, while some of the negative ecological effects have gained recognition largely in the final decades of the twentieth century. Tens of thousands of road miles built on national forest lands in the Pacific Northwest gave access to timber harvests initially, but more recently we have recognized the roads' role causing widespread erosion and damage to trout and salmon fisheries. Similarly, millions of visitors enjoy driving the paved routes through national parks, but with escalating use these roads also generate pollution and disturbance problems.

To differing perspectives, the same road can be either boon or bane. Backcountry enthusiasts might lament a road popular with weekend drivers. Other roads have simply not been maintained adequately and in their neglect cause problems ranging from inconvenient "washboard" ruts to blocked drainage culverts and massive landslides. Vehicle collisions kill hundreds of millions of animals every year, but roadkill also provides a ready food source for scavengers.

Through it all one fact remains evident and clear: roads wield a tremendous influence on the plants, animals, waters, lands, people, and natural systems of the United States (and much of the rest of the planet). A significant majority of these effects prove detrimental to biodiversity and ecosystem integrity.

Research on the ecological effects of roads comes from (and applies) beyond public lands or the boundaries of the United States. In fact, road studies include data from several continents and many types of roads. This chapter, then, addresses the ecological effects of roads generally, but with an emphasis on impacts that apply to roads most common to public lands.

Use Effects of Roads

At some point in its history, every road receives use of some kind. Activities range from the road construction work itself to a limited period of logging or resource extraction to casual recreational driving or intensive tourism. Every use of a road brings with it a different array of effects. Depending upon soils, slope, construction methods and road quality, climate, and other factors, even the same uses will lead to different effects at different times or in different places. In some areas, such as national forests or national parks, road construction can turn a formerly peaceful, remote landscape into a rolling zone of heavy industrial activity.

Of course, most roads are not only constructed, they are also driven upon. With vehicular use, new effects of roads quickly emerge. The sight of roadkilled animals has grown so commonplace to most Americans, the term now sometimes lends itself freely to recipe books, armadillo jokes, and gag food items such as prepackaged "Roadkill Helper." The amount of roadkill carnage, however, is no laughing matter: researchers estimate that 1 million vertebrates die every day on roads in the United States.[1]

Not all road use effects are as inadvertent as vehicle collisions. Hunting and fishing both lead to stress, disturbance, and mortality in wildlife and fish populations.[2] Some major hunting organizations now advocate for road closures and road removal on public lands in an effort to increase big game habitat security and improve the quality of hunting experiences.[3] Increasingly, hunters concerned with ethics and fair chase have recognized that roads and road-based hunting diminish the habitat for the animals as well as the reputations and experiences of the hunters.

On a broader scale, the human use of roads contributes to dramatic landscape conversions that can change the ecological processes, community structure, population size, and species composition of a place for the long term. From the Appalachian Mountains to the Cascades, if you see a logged forest, chances are good that you will also see a logging road. The mining industry is similarly dependent upon roads. The ranching industry also accounts for its share of road miles and use on public lands, while recreation, considered a "nonconsumptive" use of public lands by many commentators in the past, shows an increasing ability to create lasting impacts.[4]

Roads on public lands are also closely linked to developments for administrators and visitors. Human developments and use create impacts of disturbance and noise, air pollution and dust. Though chemical pollution from road use is not often as obvious as dust billowing from a passing vehicle, it is nevertheless a significant environmental effect. Road use can also exacerbate surface erosion, particularly on unpaved road surfaces. Human activity on roads provides a vector for biological invasion in many forms.

Road Construction Impacts

Even a relatively simple constructed road, such as an access route across flat Bureau of Land Management (BLM) land in the desert, requires a bulldozer to peel back the vegetation and surface soil layers to create a drivable roadbed. Few studies exist of actual plant and animal deaths caused by road construction directly, but for immobile plants and slow-moving animals on or beneath the construction route, destruction is virtually certain. With more than 8 million miles of road lanes in the lower forty-eight states (on all types of land, private and public), the land area directly covered by road surface is approximately 18,700 square miles—space enough to grade Massachusetts, Connecticut, Rhode Island, and Delaware in their entirety, and still offer 2,000 square miles of roadbed for parking.[5]

Shaving these numbers down to apply more strictly to federal lands, public land roads would still more than cover Rhode Island.[6] For a significant area of land, then, road construction has scoured natural habitat.

Vehicle Collisions and Roadkill

More than 100 people die each year as a result of vehicle–deer collisions, tens of thousands more are injured, and property damage costs range into the tens of millions of dollars.[7] Vehicle collisions kill species across the spectrum, from owls to frogs and grizzly bears to rattlesnakes.[8] In Alaska's Kenai National Wildlife Refuge, roadkill is the leading cause of death for moose.[9] On average in Pennsylvania, vehicles kill more than one black bear per week and more than 115 deer each day.[10] A Federal Highway Administration survey of selected roads in the Carolinas, Illinois, Oregon, and California counted 15,000 roadkilled reptiles and amphibians, 24,000 small mammals, and 24,000 large mammals—in a single month.[11]

Despite their ability to fly, birds also die in great numbers from vehicle collisions. The Federal Highway Administration count that sampled less than 0.3 percent of the entire interstate system still tallied more than 77,000 dead birds.[12] Although some species, such as red-winged and Brewer's blackbirds are attracted to roadside habitats and therefore comprise a large percentage of avian roadkill, the dead birds represented dozens of species with a wide range of ecological needs and habitats. The interstate highway mortality counts included, among others, mallards, mourning doves, yellow-billed cuckoos, eastern kingbirds, goldfinches, orioles, swallows, nighthawks, meadowlarks, cardinals, jays, rufous-sided towhees, dickcissels, warblers, sparrows, and grosbeaks.[13] Other studies have documented significant roadkill deaths for raptors including kestrels, northern saw-whet owls, and eastern screech owls.[14]

While high-speed vehicle collisions present a widespread threat for many large or highly mobile species, for small or slow-moving organisms even moderate road traffic on a typical public lands road can be devastating. Amphibians' small size, slow speed, and restrictive habitat and breeding requirements make them particularly vulnerable to major losses from roadkill, even on low-volume roads with relatively slow vehicle speeds.[15] Although higher traffic volumes typically lead to greater roadkill, one study estimated that a modest flow of 26 cars per hour could reduce road-crossing toads' survival rate to zero.[16] Elsewhere, 50 percent of migrating toads were killed while trying to cross a road with traffic of 24 to 40 cars per hour.[17] Vehicle-caused amphibian deaths are so widespread and numerous, some scientists now contend roadkill is a contributing factor in the global decline of frog and salamander populations.[18]

Reptiles such as snakes fare poorly on roads as well; they are attracted to warm road surfaces, move relatively slowly, and offer a large target as they crawl or stretch across roadways.[19] Regionally and federally endangered snake populations can be seriously affected by roadkill mortality, and scientists estimate that hundreds of millions of snakes may have been killed on U.S. roads in recent decades.[20]

Although roadkill obviously impacts a great number of individuals in dramatic fashion, its importance ecologically remains a matter of some debate. For common, highly adaptable species such as raccoons, blackbirds, or white-tailed deer, vehicle collisions destroy thousands of individuals every month. This may lead to important changes at the local or community level—and is certainly an issue for animal rights advocates—but overall species viability is probably not impaired by roadkill. On the other hand, populations of endemic, infecund, or rare species can be significantly impacted by vehicle collisions. The ocelot, Florida Key deer, and American crocodile are each federally designated Endangered Species. Though broader habitat protection and restoration will be crucial to the long-term survival of these species, vehicle collisions are currently their leading source of mortality.[21] In the future, as vehicle numbers or speeds increase, the impacts of roadkill on wildlife are likely to grow, not diminish.

Access for Hunting, Fishing, and Poaching

In general, with greater road access, the greater the hunting or fishing pressure becomes. Although grizzly bears are protected as a Threatened Species in Montana, Idaho, Wyoming, and Washington, each year grizzlies still die at muzzlepoint due to cases of mistaken identity during legal black bear hunts. During the spring black bear season of 2000, hunters in Montana and Wyoming mistakenly killed at least five grizzly bears.[22] Illegal poaching also contributes to bear mortality, as does the occasional self-defense killing when hunters or other armed recreationists find themselves threatened or charged. Studies have shown that the majority of grizzly bear deaths in Montana occur within 1 mile of motorized access—a result of poaching, mistaken identity hunting, vehicle collisions, and other human–bear encounters.[23] Throughout the grizzly's remaining range in the Rocky Mountains, proximity to roads and human activities has proven lethal: in northwestern Montana, 189 grizzlies have died at human hands since 1985, while in the Yellowstone ecosystem 46 grizzlies died from agency control actions, self-defense, or "other legal ways" between 1992 and 1997.[24] In 1993, the U.S. Fish and Wildlife Service identified roads as a primary factor in bear survival, stating, "Roads probably pose the most imminent threat to grizzly bear habitat today."[25]

In Yellowstone Lake, home to the world's largest population of Yellowstone cutthroat trout, illegally introduced lake trout now threaten the cutthroats' long-term prospects. Unlike cutthroats, lake trout are deepwater fish that spawn in the fall. They also eat cutthroat trout and may jeopardize the future of the area's grizzly bears, river otters, bald eagles, and ospreys who currently rely upon the cutthroat as a source of protein and calories in the spring. Yellowstone Lake is rimmed on two sides by paved roads, and without this easy road access it would have been extremely difficult to transport live lake trout into Yellowstone Lake.

Extending the Reach of Extractive Industry

As the majority of national forest road miles attest, the logging industry relies heavily upon road access. Roads enable crews to scout timber for its commercial potential, cut and clear forests, transport logs for milling and sale, and return to cutover lands for burning, post-commercial thinning, or revegetation work. While road-free helicopter or water-based logging operations are possible, these methods are seldom cost-effective or practical to implement.

Even prospectors in the gold rush days of the 1800s required roads (or railroads) to remove their ore for processing and sale; in many remote reaches of the Rocky Mountains, Sierras, Cascades, and Alaska Range, rotting roadbeds still linger from these century-old efforts. The modern mining industry often relies upon huge land-moving machines to create the open pits favored by copper and gold mining operations. Roads leading in and out of such mines must be able to handle trucks bearing hundreds of tons of ore carried on tires the size of a small house.

In southern Utah's canyon country, one of the country's most rugged and remote regions, the post–World War II uranium boom led to the development of prospecting roads on a number of lands managed by the BLM. To this day, areas featuring the uranium-rich mossback and chinle layers bear scars from the experience. Similar, even shorter-lived booms for oil shale and tar sands development sparked to life in Colorado and Utah. Long after Exxon, Chevron and other corporations pulled out of the area, the remnants of their mining dreams remain in the form of roads and drill pads in otherwise remote places.

Many ranchers and land managers drive trucks on BLM or national forest grazing allotments to work on fences, maintain water tanks, or round up livestock. The characteristic two-track roads that parallel fencelines create less soil compaction or habitat fragmentation than their heavily constructed counterparts, but such user-developed tracks are prone to erosion and gullying, play a role in plant invasions, and can facilitate secondary impacts to the area due to increased recreation or herbicides sprayed for weed control.

In addition to the long list of environmental effects caused by motorized recreation (see Chapter 5), mountain bicyclists, equestrians, cross-country skiers, and hikers each create impacts, including noxious weed dispersal, soil compaction, erosion, wildlife disturbance, and damage to vegetation.[26] More to the point, roads increase the reach and distribution of these uses by enabling recreationists to travel farther afield before launching into their activity of choice. The average wilderness hiker, for example, ventures just a handful of miles from a road-accessible trailhead, while the majority of national park visitors keep to within a few hundred yards of paved roads. Clearly, the more sprawling the road system, the more extensively recreational use will penetrate backcountry areas.

Recreational Developments and Tourism

Particularly in national parks, employee and visitor facilities have earned a reputation for their environmental impacts. Raw sewage spills in Glacier and Yellowstone National Parks made headlines in 1999 and 2000.[27] In national parks from Acadia in Maine to Big Bend in Texas, park roads and their subsequent human developments cause habituation problems for wildlife as varied as moose, marmots, mountain goats, skunks, collared peccary, and bear. In national forests, the Term Permit Act of 1915 promoted recreational developments that included thousands of lodges, cabins, developed camps, and ski areas, many of which still exist today.[28] All of these developments depended upon existing roads or their eventual construction to assure easy access.

Noise Pollution and Disturbance Impacts

Different animals respond differently to noise and disturbance. Bald eagle reproduction is known to diminish with proximity to roads, while both bald and golden eagles preferentially nest away from roads and human disturbance.[29] Sandhill cranes avoid nesting near paved and graveled roads but seem to tolerate private roads—a possible indication that the birds will adjust to low levels of consistent use.[30]

In the northern Rockies, researchers have found grizzly bears living disproportionately in the least-roaded areas of study sites. Black bears, common to public lands from Pennsylvania to California, suffer higher mortality in areas with more roads.[31] Elk and deer have been shown to avoid areas within 200 yards of heavily used roads, and in Idaho, when road densities increased beyond 2 miles of road per square mile of land, elk habitat effectiveness dropped below 50 percent.[32]

Other animals apparently choose to live in landscapes characterized by disturbance. Despite suffering high levels of juvenile mortality to roadkill, swift fox in the midwestern United States show a strong preference for road verges and typically choose den sites within 230 meters of them.[33] A study of mallards in North Dakota also found a preference for nesting near roads, though nest success in road right-of-ways was only 3 percent.[34] Other small mammal and bird species are also known to live preferentially along roadways.[35] Researchers suspect that mallards, swift fox, and other species choose nest sites and roadside habitat not from an actual affinity for roads as much as from an ability to tolerate disturbance more successfully than predators or competing species. If the advantage gained by decreased predation or competition exceeds the negative impacts of roadkill mortality or disturbance, then species might survive well in roadside habitat.

Still other species can actually thrive in disturbed landscapes. Brown-headed cowbirds, raccoons, starlings, skunks, and various rodents are well-known for their ability to handle loud, busy, and even heavily developed urban environments. Opportunistic predators such as foxes and coyotes can increase their hunting success with the long sight distances along road corridors, but these same animals may suffer from high mortality if they linger near roads. Particularly for animals dispersing from expanding populations, some individuals also manage to survive long enough to pass through heavily roaded zones between one secure habitat and the next. Studies in Minnesota have found that wolves can survive in areas with relatively high road densities as long as they are contiguous to areas with few roads.[36] Avoidance, after all, can mean many things, from using areas of habitat less than expected to altering seasonal migration patterns.[37]

Air Pollution and Dust

For residents of virtually any modern metropolitan area, automobiles and the dense network of roads are easily linked as sources of air pollution. Yet even broadly dispersed roads on public lands contribute to localized problems of air quality. Studies have found that heavy metals such as lead, aluminum, cadmium, copper, and zinc can occur in elevated levels up to 200 meters from roads.[38] Airborne lead particles, for example, are also small enough to pass through open stomata of leaves and may also be taken in by roots.[39] With the conversion to unleaded gasoline in the United States, lead contamination is less prevalent from emissions than it once was. Lead oxide in tires still poses an active source, however, and lead persists in soils and the food web for extended periods of time.[40]

Road use, especially of dirt, gravel, or other soft-surfaced roads, generates and disperses dust in levels that vary depending upon soil moisture content, particle size, and traffic volume. Road dust on plants can lead to a number of problems, including reductions in photosynthesis, respiration, and transpiration, as well as physical injury.[41]

Road Surface Treatments and Chemical Pollution

Road surface treatments—to control dust, ice, or weeds—present some of the most common and widespread forms of chemical pollution. To suppress dust on dirt roads, in the 1970s more than 100 million gallons of used crankcase oil were sprayed on roads in the United States each year.[42] With less than 20 percent of this oil binding to the road surface, some 80 million gallons were free to wash into nearby soils and streams.[43] By comparison, 1989's Exxon *Valdez* disaster dumped 11 million gallons of oil into the waters of Prince William Sound.

Road salts used for deicing also contribute a tremendous quantity of contaminants to nearby lands and waters. Deicing salts typically consist of sodium chloride, but calcium chloride, potassium chloride, and magnesium chloride are also common ingredients.[44] These salts alter soil and water pH and chemical composition, which in turn can affect plant productivity, aquatic biota, and the ecological dynamics of streams and lakes.[45] Sodium concentrations in soil can also displace nutrients critical to physiological function in plants.[46] Though deicing salts are primarily used on paved routes, with the heaviest concentrations in urban areas and highways, they are also used on many roads on federal land and can be transported easily in solution, in snowpack, as airborne particles, and on vehicles.[47] In the 1970s, highway deicing programs used 10 million tons of sodium chloride, 11 million tons of abrasives (such as sand), and 30,000 tons of calcium chloride.[48] Deicing salts can also create a dangerous roadside attraction for wildlife.

Application of herbicides along roads for weed control is standard practice even on closed road systems for many land managers, though the overall quantity of chemicals applied and their ecological impacts have not been well-studied. Common chemicals such as picloram and clopyralid are known to persist in soil for a year or longer, be highly mobile in water, and be lethal to many nontarget plants and some aquatic organisms.[49] A single national forest in western Montana reports an annual roadside application of approximately 100 gallons of herbicide to control exotic weeds such as spotted knapweed, dalmation toadflax, and leafy spurge, though this amount is only adequate to treat 0.3 percent of the weed-infested acres in the forest.[50]

Surface Erosion and Soil Loss

Although erosion increases in roaded lands with or without vehicular traffic, road use in wet conditions can create ruts that increase channelization, downcutting, and the velocity of surface flow down roadbeds. In dry conditions, road use and tire spin can scrape surface soil layers, cause uneven wear of road surfaces, generate dust, and lead to soil loss both through the air and down slopes.

Illegal, user-created roads lack the planning, grading, and maintenance of many constructed routes and are particularly susceptible to erosion from use. These "ghost" roads (eerily absent from most agency maps) often run up ridgelines, across streams, through wetlands, or on steep slopes where vehicular use even at low levels can displace soil or damage natural landscapes. The Forest Service now estimates there are more than 60,000 miles of ghost

roads on its lands and anticipates "that future inventories will verify the existence of substantially more miles of unclassified roads."[51]

Vehicles and Vectors for Invasion

Roads create many of the optimal conditions for biological invasions: a linear habitat disturbance that can extend for miles and connect with other linear disturbances, a light gap, the absence of competing vegetation (at least initially), and a route for easy dispersal—by wind, wildlife, water, or human activity.

Weeds and seeds can enter from the initial activity of road construction or from repeated uses by motor vehicles, bicyclists, livestock, pets, or pedestrians. People also introduce exotic species intentionally along roads to accelerate revegetation and decrease erosion, for aesthetics or from ignorance (including feral fruit trees started by fruit tossed from passing vehicles[52]).

Of the road-based dispersers, motor vehicles are able to travel the greatest distance in the shortest time. This makes them exceedingly effective at spreading invasions of certain types of plant seeds. In Montana, the invasion of the noxious Eurasian weed, tansy ragwort (*Senecio jacobaea*), is directly attributable to its arrival on logging equipment.[53] In Oregon and California, spores of an exotic root disease lethal to the endemic Port Orford cedar are primarily transported in soil carried by vehicles and roadway drainages.[54] A 1988 study noted that the spread of at least three other pest species in the Northwest—gypsy moth, black stain root disease, and spotted knapweed—has been facilitated by logging roads and their traffic.[55] Other types of seeds, such as the invasive hound's-tongue, form burs that cling to clothing or animal fur, which can then disperse as people or other animals travel along road corridors.

On public lands in Utah and Nevada, research determined that roadsides are substantially more invaded and contained fewer native species and more exotics than adjacent interior habitat. Improved or wider roads led to a greater percentage and abundance of nonnative species, and roads acted as conduits for invasions, especially when they passed through areas of multiple use common to BLM lands and national forests.[56]

Presence Effects of Roads

Even without human activity, roads create a number of significant ecological effects simply by their presence. These presence effects are often far-reaching, both spatially and temporally, and can combine with other presence or use effects to create dramatic impacts on landscapes and watersheds. It is important to recognize that roads have impacts even when they are closed to driving or receiving no use, since many land managers treat closed roads as if they were ecologically benign. (As discussed in Chapter 7, many road closures are also not effective at preventing all motorized use.) In fact, presence effects likely cause as many or more impacts than use effects, and often they are more difficult to mitigate or remove. Gravel and unsurfaced roads, in particular, are sources of long-term soil loss and erosion, even in the absence of vehicular use. Presence effects come in two broad classes: terrestrial and aquatic.

Terrestrial Impacts of Roads

Since the day that the first wheel mired in mud or loose soil, the presence of a compacted surface has been one of the critical and foremost features of a road. The compacted roadbed has proven itself a great asset to travel for creatures on foot, in buggies, and in motor vehicles. As a general rule, if you live or travel above ground, the more compacted the road, the swifter and easier the journey. For organisms who live or root inside the soil, however, compaction can pose a prohibitive obstacle.

Roads slice up forests and other lands to create fragments of habitat that can no longer support the number or diversity of species found in large, unroaded areas. One common way of trying to assess the degree of fragmentation caused by roads is to calculate the road density. Typically expressed as miles of road per square mile of land or kilometer of road per square kilometer of land, road density has become an increasingly useful tool for scientists and land managers to estimate the condition of the land and habitat.

While roads and their subsequent habitat changes create a competitive advantage or disadvantage for some species, for small-bodied organisms roads can create nearly impenetrable barriers to travel. With more than 1,200 square miles of public lands actually covered by roads—and an even larger amount of land subsequently affected by soil compaction, biological invasions, or light gaps—direct habitat and landscape changes from roads are substantial. Including both use and presence effects, scientists consider more than 20 percent of the contiguous United States "ecologically altered" by roads.[57]

Soil Compaction

Soil is composed of minerals, air spaces, water, and living organisms. The air spaces in soil are important for soil stability, permeability, and water absorption; as microenvironments for the living organisms in soil; and to insulate lower layers from surface heating and freezing.[58] These spaces also allow plants to establish roots and create microenvironments for the living organisms in soil. Air and water also insulate deeper layers from extreme temperature fluctuations at the soil surface. Compaction from road construction eliminates air spaces and expels water molecules, often creating a matrix that is lethal to subsoil organisms and too dense to allow plants to take root and grow.[59] In fact, road construction can increase soil density more than 200 times above that of undisturbed sites.[60]

Soil compaction can persist for decades and has been found to increase over time, even after roads are no longer used.[61] The hard surface of a road—particularly blacktopping—also increases the surface temperature. This creates abnormally warm habitat areas at night, which may in turn attract birds or reptiles and expose them to heightened risk of roadkill.[62]

Leaf litter, a key soil-building component, has also been shown to decline with proximity to roads. Soil macroinvertebrates such as insects and worms are significantly less abundant and diverse near unpaved forest roads. These impacts can then affect salamanders, birds, and other organisms reliant upon the food or shelter normally provided by these plants, soil nutrients, and invertebrates.[63]

Soil Loss

With compacted soils of unpaved roadbeds discouraging revegetation, the exposed dirt surface that remains is less stable and more prone to erosion than vegetated, undisturbed sites. Even where grasses, shrubs, or trees manage to recolonize, roads built into hillsides feature cutslopes and fill materials that are difficult to stabilize over the long term (see figure 3-1).

On open road systems, even with little to no use, roads and their verges continue to erode at a higher rate than undisturbed sites with similar char-

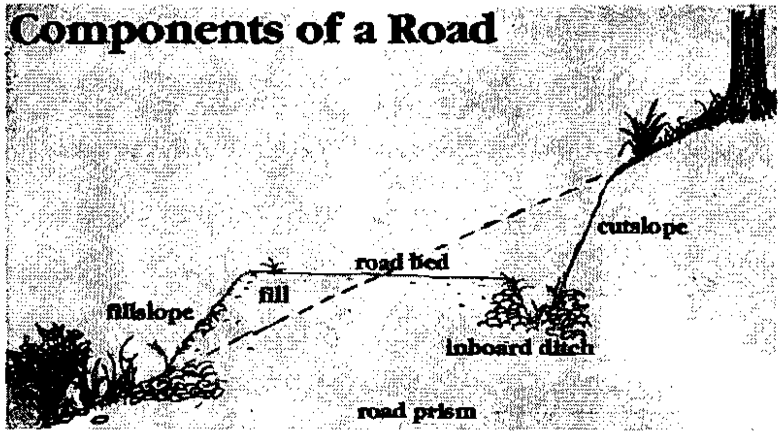

Figure 3-1: Components of a road. (Courtesy of Wildlands Center for Preventing Roads.)

acteristics. Paved roadbeds tend to hold soils in place, but cutslopes and fill material can still be highly unstable and lead to accelerated soil loss.

Habitat Fragmentation

As roads increase in number and length, the size of unroaded watersheds or habitat blocks steadily decreases. This fragmentation commonly reduces wildlife populations and creates a loss of biological diversity. For organisms adapted to conditions in a forest's shaded interior, such as the northern goshawk, spotted owl, marbeled murrelet, fisher, or woodland caribou, the diminished amount of available forage and shelter may prove insurmountable. A growing number of interior-dependent species such as these are now extirpated, endangered, or threatened in the continental United States.

Though logging practices have received well-deserved scrutiny in recent decades, roads actually create more enduring and expansive landscape fragmentation than clear-cuts.[64] Roads open forested lands to increased light, temperature extremes, and wind. With each of these changed conditions, new animal and plant species can move in and colonize areas formerly inaccessible to them. In part, this explains population and range increases for species such as raccoons, skunks, starlings, white-tailed deer, and coyotes who are able to thrive in "edge habitats" characterized by openings in the forest canopy.

Increases in edge habitat can similarly explain the historic decline of some songbirds who are unable to survive predation or edge-adapted birds. Although songbirds such as scarlet tanagers, red-eyed vireos, great crested flycatchers, or prothonotary warblers may not actively avoid thin corridor openings such as those created by roads, road gaps are wide enough to attract predatory or parasitic species such as oppossum, raccoon, and brown-headed cowbirds.[65] The parasitic cowbird is particularly effective at displacing interior songbirds, as it lays eggs in other birds' nests then leaves all rearing duties to the surrogate parents. The quick-growing cowbird young can then outcompete their more diminutive nestmates, further accelerating the cowbirds' colonization of edge habitats from one generation to the next.

A number of studies have also determined upper ranges of tolerance for species and road density. Such studies rarely distinguish whether use effects or presence effects are the key to species' survival, but for many large animals 1 to 2 miles per square mile of road density is where habitat effectiveness drops to the point of species loss or population declines. Mountain lion, elk, and wolves, for example, each show population declines as road densities rise above 1 mile per square mile.[66]

Wildlife Barriers and Corridors

Roads and other linear structures such as levees and dikes obstruct amphibians, ground-dwelling mammals, and other small, slow creatures such as snails and insects. Research has shown that roads act as barriers to salamanders and frogs trying to cross from forested areas to other habitats, but it is not clear whether the effect is due to simple avoidance or from increases in mortality[67]

Other studies have found that redback voles, dusky woodrats, white-tailed antelope squirrels, and other small mammals rarely cross onto road surfaces, even with distances as narrow as 10 feet and traffic rates of only ten to twenty cars per day.[68] Animals such as spiders and beetles have been found to cross roads—even those closed to traffic—rarely or never.[69] Roads present an obstacle even for larger animals, such as mountain lion, pronghorn, or black bear (bear crossings vary dramatically depending upon human traffic).[70]

After many generations, the isolation created by road barriers may subject small populations to increased risks from limited genetic diversity. A diminished, localized population may not be resilient enough to survive events such as floods, drought, or fire that posed only a limited threat to a large, diverse population. Similarly, with a reduced gene pool small populations can be lethally susceptible over time to the emergence of unhealthy traits or defects caused by inbreeding.

Under some conditions, roads may facilitate animal movements, reduce energy expenditures, and attract wildlife. Bison herds in Yellowstone National Park have expanded in recent years, due in large part to higher winter survival and ease of movement on roadways compacted by snowmachine use.[71] Similarly, roads cleared of snow in Alaska attract caribou, despite a subsequent increase in mortality from vehicle collisions.[72] Even grizzly bears and wolves, who generally avoid roads, will travel on closed or low-use road systems in certain conditions and seasons.

The impacts of roads on wildlife corridors are of critical importance, since in many parts of the country the most common landscape matrix is one of roads and areas strongly influenced by roads. More than 80 percent of the land in the Cherokee National Forest in Tennessee, for instance, is within a 10-minute walk from a road.[73]

Aquatic Impacts and Fisheries

Studies on deer, elk, and other prominent terrestrial wildlife species sometimes elicit the most public concern, but ecologists are increasingly pointing to roads as a factor in the decline of trout, salmon, and other aquatic populations. Sediment generated by exposed road surfaces, road-triggered landslides, and slumping slopes have contributed significantly to clogged spawning beds and diminished productivity in the waters of the Pacific Northwest and elsewhere. Endangered species listings for bull trout and Pacific salmon runs have helped to focus managers' attention on roads and the role of increased sediment in spawning redds. Some of the most significant aquatic effects of roads come from altered hydrology, or changes in the way water flows through soil and across the land.

While researchers of terrestrial species such as wolves, bear, and elk have found strong patterns of adverse effects when road densities exceed 1 mile per square mile, it is very difficult to isolate road density or any other single factor and determine how it contributes to the conditions in a specific river or stream. Many factors affect how roads impact streams, rivers, and their associated plants and animals. The distance of roads from waterways, the proportion of sand or clay in soils, the slope on which roads are built, climate, stream crossings and culvert designs, construction methods, road use, vegetation, and other qualities all relate to the way roads actually impact aquatic systems. Despite these complicating factors, there is substantial evidence that high road densities in a watershed will consistently correspond to degraded water quality and impaired fisheries.

Photo 3-1: If they are not properly maintained, culverts can clog with debris and cause serious road damage, such as this collapse in the Boise National Forest. (Courtesy of Predator Conservation Alliance.)

Roads establish barriers to aquatic systems primarily where they cross streams. Although it is possible to construct bridge and culvert crossings in a manner that causes little disruption to water flow or the passage of biota, improper maintenance or construction decisions often lead to stream crossings that create aquatic barriers. Intermittent stream channels can sometimes fill in completely, blocking reliable surface water flow and promoting large-scale "blowouts" when seasonal runoff washes away the impeding roadfill. Culverts, the large pipes used to channel water beneath road surfaces, may not be big enough to clear debris so they become clogged with organic matter, sediments, or trash, which then increases the likelihood of a road blowout (see photo 3-1). Wood or metal pipe culverts can rot or rust and fail to transport water, causing serious cross-road erosion (photo 3-2). And not least, poorly placed pipes often become

Photo 3-2: Undersized or clogged culverts may fail to drain properly, causing water to flow across roads and cause damage. (Courtesy of Redwood National Park.)

hanging or "shotgun" culverts that poke several feet out from the road prism or streambed, making upstream migrations impossible and carving deep erosion pits where the water plunges against the slope below.

Sedimentation and Erosion

In areas with high road densities, steep slopes, and unstable soils—which occur with some frequency in trout and salmon habitat in Idaho, the Cascades, and Sierra Nevada—roads combine with dams, overfishing, and impacts from logging as an important cause of population declines. A Montana study of watersheds in threatened bull trout habitat found that healthy trout populations correlated most strongly with an absence of roads.[74] Many scientists now recognize that the healthiest remaining bull trout populations exist in the least-disrupted watersheds.[75]

Studies of more than 1,400 landslides in the Boise and Clearwater national forests in Idaho found that 88 percent were road related. Elsewhere, on Idaho's South Fork of the Salmon River, 80 of 89 slides were associated with roads.[76] Research on the nearby Payette National Forest also linked levels of fine sediments in streams to road densities.[77]

Researchers have established that "roads are the primary cause of accelerated erosion and sedimentation"[78] in watersheds and that average surface erosion rates increased 220 times on lands with timber roads compared to undisturbed forest slopes.[79]

Since many freshwater species—from aquatic invertebrates such as stonefly and mayfly larvae to the trout and salmon who feed on them—depend upon clear, cobbled substrates for some stage of their life cycles, a sediment-clogged stretch of river can lead to severe declines in species' vigor and abundance.

Barriers to Fish Migration

Problems caused by poorly maintained stream crossings and road culverts are far from hypothetical. The Forest Service has identified a massive maintenance and reconstruction backlog on national forest roads.[80] Poorly maintained culverts and their accompanying impacts on water quality and stream connectivity are consistently one of the largest items of concern for poorly maintained roads. A study in Idaho determined that nearly 20 percent of the significant road-related erosion problems involved malfunctioning or poorly maintained culverts.[81] Another study asserted that *all* culverts that are abandoned and not properly maintained will eventually fail.[82]

Paradoxically, unmaintained or hanging culverts have been implicated in both species imperilment and species protection. Whereas the broken connectivity of a stream channel can sever headwater areas from trout or salmon populations attempting to migrate to historic spawning redds, on occasion such isolation has also protected localized populations from genetic dilution or competition from introduced species downstream. Headwaters populations of westslope cutthroat trout in southwestern Montana, for instance, include some of the few genetically pure strains found anywhere. With introduced rainbow or Yellowstone cutthroat trout living downstream, land managers attribute the headwater populations' purity to hanging culverts and poorly maintained road crossings that have prevented migration and interbreeding between the populations.[83]

Hydrologic Changes from Roads

On a naturally unroaded slope, water from rain or snowmelt percolates into soil and gradually flows downhill. Moving through the air spaces in

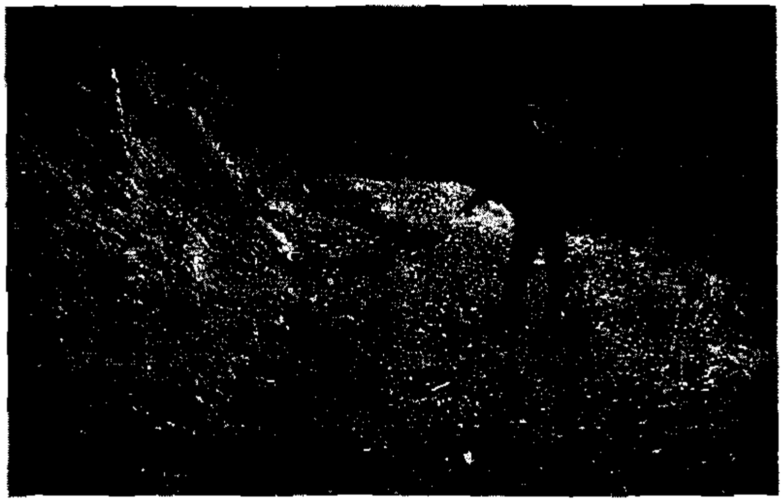

Photo 3-3: Road surface erosion caused, in part, by the conversion of water from subsurface to surface flow.

uncompacted soil, this "sheet flow" of water causes little erosion and takes place steadily and slowly throughout the year. Springs and hillside wetlands often exist where subsurface water intersects a natural depression or shelf of bedrock and flows to the surface.

Road construction triggers multiple changes in the hydrology of a slope and converts gentle, subsurface flow into more rapid and concentrated runoff at the surface. The cutslope at the uphill edge of a road interrupts subsurface water and redirects it to roadside ditches, cross-road culverts or the road surface (photo 3-3). With roads converting the diffused sheet flow beneath the surface to a more concentrated pulse of surface water, roaded areas experience peak flows (i.e., seasonal runoff) characterized by higher volumes that crest more quickly.[84]

When combined with clear-cuts, roads produce significant long-term increases in both the magnitude and the duration of peak flows, essentially creating conditions more prone to flooding.[85] Higher peak flows also increase soil erosion and sediment loads carried into streams, rivers, and lakes.

In fitting testimony to the complexity of natural systems, roads not only contribute to the disruption of aquatic systems, but also unnaturally *mix* the flow of formerly distinct watersheds. By cutting across slopes and converting subsurface flow to surface runoff, some roads carry water originally destined for one watershed and channel it into neighboring drainages. Such road-generated transbasin diversions pale in comparison to intentional diversion projects in the Tennessee Valley, Colorado Front Range, or desert Southwest, but for small drainages high in a watershed or for spring-fed systems, even these minor shifts in runoff can seriously alter the local landscape and its residents. If a spring dries up because a road upslope diverts subsurface flow out of the drainage basin, then the community of animals and plants that once depended upon that oasis may be displaced or perish.

Implications of the Ecological Effects of Roads

An abundance of roads can carry obvious benefits to transportation and commerce, but the long-term ecological consequences may be slower to unfold. "Hyperfragmentation," which includes the combined effects of habitat loss and fragmentation on both terrestrial and aquatic ecosystems, may lead to ever more serious problems of water quality, diminished wildlife habitat, species imperilment, and biological impoverishment in the years ahead.[86] Furthermore, the effects of a road may extend for more than a mile from the road itself and the full impacts may not emerge for dozens of years.[87] In other words, our assessment of ecological conditions today may better reflect the activities and road densities from several decades ago than the true impacts of today's roads and landscape changes.[88]

Although a number of the effects of roads have likely not yet even emerged, we can apply what we know now to try to anticipate our future needs and values. For public lands with specific management directives, what we know about roads and their ecological effects ought to play an important role in agency decisions. The National Wildlife Refuge System, for example, is dedicated primarily to the conservation of fish, wildlife, and plants. Information about the ecological effects of roads should be relatively easy to incorporate into refuge plans to help managers meet their conservation objectives. Unfortunately, even on our public lands with the clearest mandates, the relevant science of roads can become subverted to local or political pressures.

Such pressures highlight the need for well-informed citizens to participate in public land decisions, many of which involve questions of roads and access. Whether to protect and restore salmon runs in the Pacific

Northwest or endangered crocodiles and panthers in Florida, how we manage road systems makes a dramatic difference. By engaging in the public decision-making process, citizens and conservationists can play an important role in determining how public lands will be managed and that we apply science appropriately.

Our understanding of the ecological effects of roads can also help shape specific management decisions. When presence effects of roads are the dominant problem, managers should work on road surface treatments, stream crossings, soil decompaction, or other habitat restoration measures. When use effects are the overriding problem, then simple road closures might suffice, as long as closures can be made effective over time. Where both use and presence effects cause problems—and often they do—then we can turn to full road removal projects such as those described in Chapter 7. In many cases what benefits the land, water, or wildlife most will also prove to be most economical in the long term.

Although we know enough already to make many ecologically informed and responsible decisions, our management of public lands will surely benefit from a deeper understanding of road impacts on aquatic systems in particular. Scientists may struggle to identify a specific road density, for example, that correlates to specific losses in salmon or trout habitat, but conscientious management policies would have us err on the side of caution in the presence of uncertainty. Ongoing research to identify the range of historic conditions can also help us determine how dramatic or acceptable road impacts may be in different areas.

You do not need to be a roads activist or a land manager struggling with access issues to care about public land roads. In time, it may take nothing more than a desire for clean drinking water from the tap to discover that these roads can affect us all.

Although we will turn more fully to values and identifying the public good in the chapters ahead, much of the debate over public land roads and motorized access also centers upon money and politics. From the halls of power in Washington, D.C., to rural county seats across the West, funding programs and political battles profoundly influence where bulldozers or wheels can turn open spaces into roaded places. Whether we are facing rebellious counties in Utah or pork-barrel politics in Congress, in order to engage road and motorized access issues effectively we will need to understand the existing political and financial structures.

Considering the many benefits and uses of a transportation network across the National Forests, it is difficult to understand why roads have been under siege in recent years.

—U.S. Representative Larry Combest
(R-TX), May 1997

4 | The Cutting Edge: Money, Politics, and Access

A map on my wall shows the roads of the Roman Empire. For many years I was intrigued by these roads that radiated from Italy to reach lands as far away as England, Romania, Syria, and northern Africa. The Appian Way and other names echoed with history and set me thinking of worn cobblestones, red tiled roofs, and freshly baked pizza. More recently, I noticed a background of other names on the map—lead, iron, grain, timber—and I began to think about the motives for those ancient routes, and of the labor and expense of building and maintaining miles of cobblestone.

In many ways, I have come to public land roads over a similar path. National forest and park roads that once sounded scenic and free now ring with costs that I never imagined. Even relatively modest dirt or gravel roads through wildlife refuges and Bureau of Land Management (BLM) lands, I have learned, cost tens of thousands of dollars per construction mile. Simply to provide proper maintenance of the sprawling public lands road system would cost more than $10 billion.

For more than eight decades, the U.S. Congress and federal agencies have made it a priority to fund roadbuilding across national forests, into the heart of national parks, through wildlife refuges, and on BLM resource areas. The money flowed and we have the roads to show for it.

Service Roadless Area Conservation Final Conservation Impact Statement, p. 3–28.

103. *Report of the Forest Service*, FY 1985, pp. 31–32.
104. *Roads in the National Forests*, May 1988; *Roads in the Rocky Mountain Region*, 1988.
105. *Administration of the Forest Development Transportation System: Temporary Suspension of Road Construction in Roadless Areas*, U.S. Department of Agriculture, Forest Service, p. 2.
106. Even the moratorium that applied to roadless area developments had its loopholes: areas smaller than 5,000 acres were excluded, as were all forests that had recently completed forestwide planning documents.
107. *Report of the Chief*, 1935, p. 36.
108. *1999 Status of the Nation's Highways, Bridges and Transit*, p. E-3.
109. Adams, Treadmarks on the virgin land: The appropriate role of off-road vehicles in national forests, provides good background information on the development of off-road vehicle technology.
110. According to Cartographic Technologies in Brattleboro, Vermont, Thorofare in Wyoming is 20 miles distant, the second most remote location is 18 miles in the Bob Marshall Wilderness complex of north-central Montana, while a point in Idaho's Frank Church–River of No Return Wilderness comes in third at 16 miles. These rankings do not include Alaska. See also, Black, Yellowstone outpost most remote in U.S., p. A-2; also, personal communication with Susan Boswell, Cartographic Technologies Inc., 14 December 2000.

Chapter 3. The Ecological Effects of Roads

1. Forman and Alexander, Roads and their major ecological effects, p. 213. Countless insects also die each day from vehicle impacts. Note that this figure includes highways and other roads generally beyond the scope of this book.
2. Trombulak and Frissell, Review of ecological effects of roads on terrestrial and aquatic communities, p. 24.
3. See, for example, the Boone and Crockett Club's summer 1999 issue of *Fair Chase*, or the summer 2000 issue of *Mule Deer*, published by the Mule Deer Foundation. The Rocky Mountain Elk Foundation has also sponsored work parties to reduce road densities in big game habitat.
4. For recreation as nonconsumptive use, see for example Laitos and Carr, The transformation on public lands, p. 144.
5. See Trombulak and Frissell, Review of ecological effects, p. 19, for square mileage of road surfaces. Massachusetts has an area of 8,257 square miles, Connecticut 5,009, Rhode Island 1,214, and Delaware 2,057.
6. Assuming an average road width of twelve feet, the 550,000 miles of road on these lands amounts to 1,250 square miles.
7. Romin and Bissonette, Deer–vehicle collisions: Status of state monitoring activities and mitigation efforts, pp. 276–277, report that approximately 120 people die from vehicle–deer collisions in an average year. Over a four-year period, Michigan recorded 3,289 injuries to motorists as a result of collisions with deer; between 1981 and 1991, the State of Vermont registered more than $31 million of property damage (primarily to automobiles) from cars hitting deer.
8. Most roadkill studies relate to interstate highways, state or county roads, and other paved routes where high speed and high traffic volumes make a particularly lethal combination.
9. Bangs, Bailey, and Portner, Survival rates of adult female moose, pp. 557–563.
10. Noss, *The Ecological Effects of Roads or the Road to Destruction*, p. 11, reports that more than ninety black bears were killed by vehicle collisions in Pennsylvania in 1985; Romin and Bissonette, Deer–vehicle collisions, p. 278, report 43,002 deer killed by vehicles in Pennsylvania in 1990.
11. Adams and Geis, *Effects of Highways on Wildlife, Final Report*, p. 105.
12. Adams and Geis sampled 118 miles of interstate highway and 120 miles of country roads; 85 percent of the roadkills they recorded were on or along the interstate highways, pp. 101, 105.
13. Adams and Geis, pp. 106–110.
14. Varland, Klaas, and Loughlin, Use of habitat and perches, causes of mortality and time until dispersal in post-fledging American kestrels, pp. 169–178; Loos and Kerlinger, Road mortality of saw-whet and screech owls on the Cape May Peninsula, 210–213. Despite its limitations of scope and size, the Loos and Kerlinger study found multiple vehicle-caused mortalities to sharp-shinned hawks, broad-winged hawks, American kestrels, red-tailed hawks, great horned owls, and barred owls.
15. Gibbs, Amphibian movements in response to forest edges, roads and streambeds in southern New England, p. 584.
16. Fahrig et al., Effect of road traffic on amphibian density, p. 177, citing G. Heine, 1987, Einfache Meß- und Rechenmethode sur Ermittlung der Überlebenschance wandernder Amphibien bein Überqueren von Straßen, *Beihefte zu den Veröffentlichungen för Naturschutz und Landschaftspflege in Baden-Württemberg* 41: 175–186.
17. Fahrig et al., p. 177, citing J. Kuhn, 1987, Straßentod der Erdkröte (*Bufo bufo L.*): Verlustquoten und Verkehrsaufkommen, Verhalten auf der Straße, *Beihefte zu den Veröffentlichungen för Naturschutz und Landschaftspflege in Baden-Württemberg* 41: 175–186.
18. Fahrig et al., p. 177.
19. Rosen and Lowe, Highway mortality of snakes in the Sonoran Desert of southern Arizona, p. 143.
20. Rosen and Lowe, p. 147; Dalrymple and Reichenbach, Management of an endangered species of snake in Ohio, USA, pp. 195–200.
21. Noss, *Ecological Effects*, pp. 11–12; Jenkins, *Texas Department of Transportation Wildlife Activities*, pp. 199–231; Kushlen, Conservation and management of

the American crocodile, p. 783. See also Noss et al., Conservation biology and carnivore conservation in the Rocky Mountains, p. 958, citing L.D. Harris and P.B. Gallagher, 1989, New initiatives for wildlife conservation: The need for movement corridors. In *Preserving Communities and Corridors*, G. MacKintosh, ed., pp. 11–36. Washington, D.C.: Defenders of Wildlife; and Willams, The ghost cat's ninth life, p. 76.

22. McMillion, At least five grizzlies mistakenly killed by black bear hunters, pp. A-1, A-8.
23. Dood, Brannon, and Mace, *Final Programmatic Environmental Impact Statement: The Grizzly Bear in Northwestern Montana*; Aune and Kasworm, *Final Report East Front Grizzly Studies.*
24. See Jamison, National Park Service makes resource protection top priority, pp. A-1, A-7 for NW Montana figures; McMillion, At least five grizzlies mistakenly killed, pp. A-1–A-8 for Yellowstone data.
25. *Grizzly Bear Recovery Plan*, p. 22.
26. Weaver and Dale, Trampling effects of hikers, motorcycles, and horses on meadows and forests, pp. 451–457; Seney, Erosional impact of bikers, horses, off-road bicycles, and motorcycles on mountain trails; Freddy, Bronaugh, and Fowler, Responses of mule deer to disturbance by persons afoot and snowmobiles, pp. 63–68. See also generally, Hammitt and Cole, *Wildland Recreation: Ecology and Management.*
27. Devlin, Open valve dumps sewage into Lake McDonald, pp. A-1, A-3; Moen, Yellowstone sewage system overwhelmed, p. B-5.
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30. Norling, Anderson, and Hubert, Roost sites used by sandhill crane staging along the Platte River, Nebraska, pp. 253–261.
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32. Rost and Bailey, Distribution of mule deer and elk in relation to roads, pp. 634–641. Lyon, Road density models describing habitat effectiveness for elk, pp. 592–595.
33. Sovada, Roy, and Woodward, Swift fox mortality in grassland and cropland landscapes of western Kansas; Hines and Case, Diet, home range, movements, and activity periods of swift fox in Nebraska, pp. 131–138.
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37. See Horejsi, Gilbert, and Craighead, *British Columbia's Grizzly Bear Conservation Strategy: An Independent Review of Science and Policy*, p. 9.
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41. A.M. Farmer, The effects of dust on vegetation: A review, pp. 63–75.
42. Noss, *Ecological Effects*, p. 14. This treatment is still relatively common on private roads. See also Payne and Martins, Crankcase oils: Are they a major mutagenic burden in the aquatic environment? pp. 329–330.
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46. Wood, Roads and toxic pollutants, p. 11, bibliography notes citing A.M. Fleck, M.J. Lacki, and J. Sutherland, Response by white birch (*Betula papyrifera*) to road salt applications at Cascade Lakes, New York, *Journal of Environmental Management* 27(4): 369–378; and G. Hofstra and D.W. Smith, The effects of road de-icing salt on the levels of ions in roadside soils in southern Ontario, *Journal of Environmental Management* 19: 261–271.
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48. Noss, *Ecological Effects*, p. 14.
49. Information from U.S. Department of Agriculture fact sheets on Clopyralid and Picloram, available online: http://www.fs.fed.us/foresthealth/pesticide/clopyralid.html and http://www.fs.fed.us/foresthealth/pesticide/picloram.html. Clopyralid is often marketed under the trade names Transline, Stinger, or Reclaim, while picloram is marketed as Tordon.
50. Personal communication with Lolo National Forest Missoula District Ranger Andy Kulla, 19 July 2000. The Lolo NF treated 871 acres with herbicide in 1999, at an average application of one pint/acre for picloram (other chemicals are applied in different quantities, but picloram is the one most commonly used on the Lolo). Kulla reports 280,000 acres of weeds on the Lolo National Forest.
51. *Administration of the Forest Development Transportation System: Advance Notice of Proposed Rulemaking*, p. 2. Conservationists contend that even this figure

underrepresents the actual number of user-created routes on national forests, and the Forest Service acknowledges this as well: "It is anticipated that future inventories will verify the existence of substantially more miles of unclassified roads" (National Forest System Facts, http://www.fs.fed.us/news/roads/factsheet.shtml [18 July 2000]).

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61. Vora, Potential soil compaction, p. 117; and Trombulak and Frissell, Review of ecological effects, p. 21, citing J.D.Helvey and J.N. Kochenderfer, Soil density and moisture content on two unused forest roads during first thirty months after construction, Research paper NE-629, U.S. Forest Service, Northeast Forest Experiment Station, Broomhall, PA.
62. Trombulak and Frissell, Review of ecological effects, citing P.C. Whitford, Bird behavior in response to the warmth of blacktop roads, *Transactions of the Wisconsin Academy of Sciences Arts and Letters* 73: 135–143.
63. Haskell, Effects of forest roads on macroinvertebrate soil fauna of the southern Appalachian Mountains, pp. 59–61.
64. Reed, Johnson-Barnard, and Baker, The contribution of roads to forest fragmentation in the Rocky Mountains, pp. 1098–1106.
65. Rich, Dobkin, and Niles, Defining forest fragmentation by corridor width: The influence of narrow forest-dividing corridors on forest-nesting birds in southern New Jersey, pp. 1109–1121.

66. Van Dyke et al., Reactions of mountain lions to logging and human activity, pp. 95–102; Lyon, Road density models for elk, pp. 592–595; Thiel, Relationship between road densities and wolf habitat suitability in Wisconsin, pp. 404–407; Mech et al., Wolf distribution and road density in Minnesota, pp. 85–87.
67. Gibbs, Amphibian movements in response to forest edges, roads, and streambeds in southern New England, pp. 584–589.
68. Oxley, Fenton, and Carmody, The effects of roads on populations of small mammals, p. 57; Mader, Animal habitat isolation by roads and agricultural fields, pp. 85–86; Swihart and Slade, Road crossing in *Sigmodon hispidus* and *Microtus ochrogaster*, p. 357.
69. Mader, Animal habitat isolation, p. 85.
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71. Yellowstone Science interview: Mary Meagher "The Biology of Time," p. 16. These larger herds are subsequently trying to expand beyond the boundaries of the national park, which has led to the controversial bison shootings each winter by the Montana Department of Livestock (DOL). Montana's DOL killed more than 1,000 Yellowstone bison during the winter of 1996–1997.
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Chapter 4. The Cutting Edge: Money, Politics, and Access

1. *Transportation Equity Act for the 21st Century: A Summary*, p. 20.
2. Federal Lands Highway, Federal Lands Highway Programs, U.S. Department of Transportation, Federal Highway Administration, available online: http://www.fhwa.dot.gov/flh/flhprog.htm, visited August 16, 2000. The Federal Lands Highway Program came with the passage of the Surface Transportation Assistance Act in 1982 that later led to 1998's TEA-21.
3. Federal Lands Highway, Overview, available online: htttp://www.fhwa.dot.gov/flh/flhprog.htm [16 August 2000].
4. Federal Lands Highway, available online: wysiwyg://284/http://fhwa.dot.gov/flh/index.htm [16 August 2000].
5. Federal Lands Highway, Federal Lands Highway Programs, available online: http://www.fhwa.dot.gov/flh/flhprog.htm [16 August 2000]. See also, *Transportation Equity Act for the 21st Century: A Summary*, pp. 44–45.
6. Personal communication with Sean Furniss, U.S. Fish and Widlife Service, Refuge Program Specialist, 19 September 2000.
7. U.S. House of Representatives, *Future Maintenance and Repair of the Going-to-the-Sun Road in Glacier National Park: Field hearing before the Subcommittee on National Parks and Public Lands*.
8. Glacier National Park, press release, 4 February 2000.
9. Personal communication with Mike Roy, U.S. Fish and Wildlife Service, June 2000.
10. P.L. 105-78, sec. 115(e)(k)(1). According to the Fish and Wildlife Service's Sean Furniss, the provision that money could not be used to construct new roads was included in order to preclude a proposal to build the controversial road into the Izembek National Wildlife Refuge in western Alaska, not from any broader congressional concern about road impacts.

11. Sean Furniss noted that refuge lands are administered by a relatively small corps of employees—approximately 2,500—compared to the other land management agencies, and that "traditionally we've been at the low end" for agency funding.
12. *Transportation Equity Act for the 21st Century: A Summary*, p. 20; also, Federal Lands Highway Programs, Emergency Relief for Federally Owned Roads, available online: http://www.fhwa.dot.gov/flh/erfo.htm [16 August 2000].
13. Walder, ERFO fact sheet, Wildlands Center for Preventing Roads; Personal communication with Anne Connor, Clearwater National Forest, 29 March 2001; personal communication with Mike Sanders, Redwood National Park, April 2001. ERFO funds can be applied to road obliteration up to the amount it would have cost to replace the damaged road segment.
14. *Public Land Statistics*, U.S. Department of the Interior, BLM, annual reports from 1949 to 1999.
15. Purchaser credits were not to exceed a minimum price required for the sale, and a 10 percent performance bond was required in advance. Purchasers also had to pay approximately 20 to 25 percent of the sale price as a downpayment on the sale.
16. Much of this information comes from an interview with Charlie Sells, USFS Region One timber sale contract specialist, Missoula, MT, 15 September 2000.
17. The Federal Wage and Concessions Act, for example, requires the Forest Service to calculate costs using union wage scales. Private logging companies are not so bound.
18. Personal communication, July 1994, with timber crew foreman, Anita Bay, Etolin Island, Alaska.
19. U.S. House, *Financing of Roads in the National Forests: Hearing before the Subcommittee on Forestry, Resource Conservation, and Research*, noting a Price Waterhouse study submitted to subcommittee, p. 9.
20. *Financing of Roads*, p. 9.
21. See Clawson, *The Bureau of Land Management*, for background on the O & C Lands; O & C Lands road mileage from 1999 *Public Land Statistics*, Table 6-2.
22. Personal communication with Joe Casey, BLM Forester, Dillon, MT, 20 September 2000.
23. See, *Financing of Roads*.
24. *Financing of Roads*, p. 5, testimony from Congressman George E. Brown Jr., D-California.
25. Charlie Sells, 15 September 2000.