4 Wildlife

The effects of wildland recreation on wildlife have received little systematic attention, resulting in a knowledge base that is disparate and seldom definitive. This is because wildlife species are not stationary, as are plants, and the effects of impacts are not immediately obvious, direct, or easily measured. Nevertheless, numerous impacts to wildlife as a result of recreation have been documented, and in some cases well researched (Ream 1980; Boyle and Samson 1985; Knight and Gutzwiller 1995). Boyle and Samson, for example, reviewed 166 articles that contained original data on the effects of nonconsumptive outdoor recreation on wildlife. These studies show that human disturbances result in changes in wildlife physiology, behavior, reproduction, population levels, and species composition and diversity. Studies also show that there are at least six factors of recreational disturbances that influence wildlife responses: type of recreational activity, recreationists' behavior, impact predictability, impact frequency and magnitude, timing, and location (Knight and Cole 1995). In many cases the major source of wildlife impacts is the recreationist who innocently produces stressful situations for wildlife, primarily through unintentional harassment of wild animals. However, some wildlife are attracted to recreationists and alter their behavior in response to the presence of humans. Panhandler black bears and chipmunks in campgrounds that seek out human foods are typical examples. This chapter reviews the major types of ecological disturbances caused by recreationists-wildlife interactions and the major impacts on some species of animals where management problems are most evident.

RECREATION INFLUENCES ON WILDLIFE RESPONSES

There are many recreation-related factors that influence the responses of wildlife when disturbed. It is important to have an introduction to and understanding of these major factors before advancing to specific types of recreation-wildlife impacts and the animals affected.

As mentioned earlier, Knight and Cole (1995) recognize six factors of recreational disturbances that influence wildlife responses. The first of these is *type of activity*. There are many types of recreational activities, each differing in activity style, equipment used, habitat occupied, and animal interactions (see Chapter 4 in Knight and Gutzwiller 1995 for a discussion of individual activities). Motorized types of activi-

ties—with their speed, area covered, and noise—certainly have different influences on wildlife response than nonmotorized activities. Noise associated with aircraft, boats, and all-terrain vehicles is a factor of great concern in managing wildlife impacts (Bowles 1995).

The *behavior of recreationists* when carrying out recreational activities and interacting with wildlife can have a profound influence on wildlife responses. A person's rapid movement directly toward wildlife frightens them, whereas movement away from or at an oblique angle to them, and at a slower speed, has less influence. *Predictability* of events and of recreationists' behavior is also an important factor affecting wildlife response. "When animals perceive a disturbance as frequent enough to be expected and nonthreatening, they show little overt response" (Knight and Cole 1995, p. 72). On the other hand, animals react quite differently when they perceive disturbance as predictable and threatening. Birds are particularly sensitive in this respect.

The *frequency and magnitude* of disturbance influences the reactions of wildlife. A number of studies have shown that the nesting behavior and reproductive success of birds are negatively influenced when nesting areas are frequently visited. However, thresholds of disturbance frequencies above which critical levels of impacts to wildlife may occur are poorly understood. For example, number of hunters afield, hours of hunting per unit area, hiker intensity on trails, and road traffic loads are known to influence animal movement, feeding habits, and habitat occupation, but few threshold levels have been identified for these factors.

Timing and *location* factors involve the season of year and the space in which wildlife are disturbed. The breeding season for animals is a critical time, when recreation disturbance may be most detrimental. Wildlife may respond during the breeding season by abandoning nests or young, which can lead to total reproduction failure. Recreational activity can also alter parental attentiveness, thus increasing the risk of the young being preyed upon, disrupting feeding patterns, or exposing the young to adverse environmental stress. As indicated in the case studies in Knight and Gutzwiller's book (1995), bird studies dominate research in this area. Recreational disturbance outside the breeding season can also be quite influential, particularly in ways that potentially reduce energy acquisition (i.e., foraging) or increase energy expenditure (i.e., fleeing). Closely related to breeding season disturbances are nest and den location impacts. Disturbance that occurs in feeding and watering locations is also an important factor influencing animal response. Moreover, research has shown that many animals perceive activities that occur above them to be a greater threat to their safety and ability to escape than activities below. Bighorn sheep, peregrine falcons, and some other wildlife are particularly sensitive when approached from above.

In addition to the aforementioned six factors that influence wildlife response to disturbance, there are also certain characteristics of wildlife that shape their responses to disturbance. Just as the type of recreational activity can be important, so is the *type of animal* important. "Animals with different life-history traits and evolutionary strategies

(e.g., longevity, parental care, reproductive effort) vary in their reactions to recreational disturbance" (Knight and Cole 1995, p. 74). Species with specialized food and shelter requirements and other limiting factors are more vulnerable to disturbance than are species with more generalized requirements. *Group size* also influences disturbance response. In general, animals in groups respond to approaching threats at greater distances and are less sensitive to disturbances than solitary individuals. The *age* and *sex* composition of groups also influences their response. Females with young are more likely to flee when disturbed than groups without young. For example, Singer and Beattie (1986) found that cow and calf groups of caribou in Alaska were more likely to react than all cow groups, and bull groups were least likely to flee.

HUMAN-WILDLIFE INTERACTIONS

The response of wildlife to recreational disturbance is complex, being neither uniform nor consistent. Different species of wildlife have different tolerances for interactions with humans. Although some species may be completely displaced from an area of concentrated recreational use, other species have actually increased in abundance. In general, species less tolerant of recreational disturbance will be replaced by those better adapted to the new environmental conditions (Kuss, Graefe, and Vaske 1984).

Even within a species, tolerance levels for interactions will vary by time of year, breeding season, animal age, habitat type, and individual animal experience with recreationists. Recreationists may produce critical situations at certain times and places but have no effect on the same species or individuals under other conditions. Seasonal and spatial effects appear to be strongly tied to habitat requirements and utilization (Anderson 1995). For example, if a species is already under physiological stress from limited food and other environmental factors, interactions with humans may be especially serious.

The relationship between amount of recreational use and wildlife impacts is not well understood. Very few studies have systematically examined the effects of varying numbers of visitors on wildlife. Even fewer wildlife studies have determined an accurate population count of organisms prior to the introduction of recreation. There is also a lack of studies that have systematically controlled for environmental and population dynamic influences during recreation use and impact studies. Thus, it has been difficult to document a uniform relationship between amount of recreational use and wildlife impacts. In fact, there may be no *uniform* relationship. Previous research indicates the complexity of the relationship by stating that the number of visitors cannot be considered in isolation from species requirements and habits, population dynamics, setting attributes, and type of recreational use. Various aspects of use intensity are also involved, including frequency and regularity of use and number of people at one time (Speight 1973; Knight and Gutzwiller 1995). There is evidence that the effects of human-wildlife interactions depend more on the frequency of human presence than on the amount of total recreational use or on the number of people present at any one time.

Although human-wildlife interactions are too complex to classify, an attempt to generalize about the form of impacts may be useful. The influence of wildland recreation on wildlife occurs in the forms of *direct* and *indirect* impacts. Direct impacts include the effects on animals caused by primary disturbances and interactions with humans. Indirect impacts are the secondary results of disturbances to habitat and other environmental parameters as a result of recreational use of natural environments. Although indirect impacts of human-wildlife interactions are secondary in nature, they are far more prevalent in affecting most wildlife (Speight 1973; Cole and Landres 1995). Cole and Landres (1995, p. 193) state that "indirect impacts differ from direct impacts in two ways: (1) indirect impacts are inevitable, occurring wherever and whenever recreational use occurs; and (2) they generally occur over long periods of time, with effects that are long-lasting and that may take place only after a time lag." According to Kuss, Graefe, and Vaske (1984), "Larger game species tend to be affected more by direct contact with people while smaller forms of wildlife appear to be more susceptible to indirect impact on habitat."

Recreational impacts on wildlife may also be classified as *selective* versus *nonselective*. Selective impacts are associated with recreational activities that focus on certain wildlife species. For example, nature study and collecting as well as hunting and fishing are often restricted to a limited number of species and, in some cases, unique or rare species. Nonselective impacts result from coincidental interactions by visitors of whatever wildlife they confront. Hiking, camping, and picnicking are activities that typically lead to nonselective impacts.

As with any attempt to generalize or classify complex phenomena, obvious overlap and interrelatedness exist among parameters. Hunting has been studied more than any other human-wildlife interaction and demonstrates well the difficulty of classifying impacts. Although hunting would at first appear to be a form of direct, selective impact, it also results in indirect and nonselective forms of disturbance. Habitat manipulation for certain game species can have detrimental effects on nongame species. Introduction of exotic species for hunting purposes also has indirect impacts on native species. Regulated hunting of animals is considered to be very selective, resulting in the management of specific wildlife populations on a sustained basis. However, even here the impacts are not as selective as one might wish. Speight (1973) reports a study in which 30 percent of wildfowlers could not distinguish game species from rare, protected species. Salo (in Wall and Wright 1977) found that wounding rates in hunting appear to range between 24 and 30 percent. The point is best summarized, although exaggerated, by a chief naturalist at Yellowstone National Park who stated, "In order to get 5000 elk shot by hunters, it would be necessary to accept that in addition 196 moose, 17 men, and an undetermined number of bears, coyotes, bighorn sheep, antelope, bison, mule deer, and horses would be shot by mistake" (Fraser and Eichhorn 1969).

Obviously, the many parameters related to human-wildlife interactions are complex. Nevertheless, understanding these parameters is essential if recreational impacts on wildlife are to be managed.

RECREATION-WILDLIFE IMPACTS

The intrusion of humans into wildlife habitats during recreational activities can cause various types and levels of change in both animals and their habitat. These changes are not entirely detrimental to animals; although many animals are repelled by the presence of humans, others are attracted. Neither are all the changes a direct result of contact with humans; some are indirect. Figure 1 presents a conceptual framework of the major impacts associated with recreational activity in wildlife areas. Alternative frameworks are offered by Pomerantz, Decker, Goff, and Purdy (1988); Kuss, Graefe, and Vaske (1990); and Knight and Cole (1995).

When recreational activity occurs in wildlife habitats, two forms of interaction can occur. The recreationists may interact with the animals directly or indirectly through altering the habitat. Direct interaction with wildlife results in two major types of impact: various levels of disturbance and harassment and the actual killing of animals. These two impacts, along with habitat modification, can lead to three responses by wildlife. First, the normal behavior of animals may be altered to various degrees, all the way from habituation to slight modifications to migration from impacted sites. Second, animals may be displaced completely to a new habitat or, in the case of sport hunting, displaced from the population. Third, all three impacts can cause a reduction in the reproductive level of many species. Ultimately, these impacts result in a change in the species composition and structure of wildlife populations. The major impacts presented in Fig. 1 will now be briefly discussed.

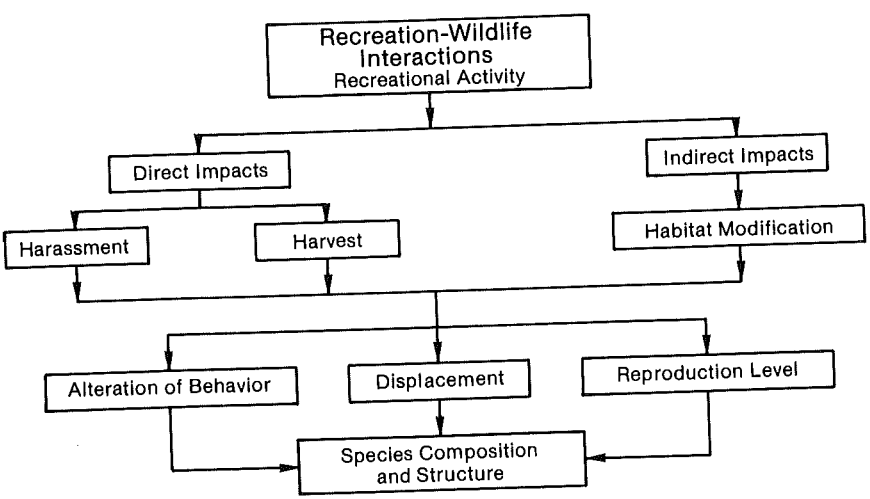

FIGURE 1. Major impacts of recreation-wildlife interactions. (*Source*: Adapted from Wall and Wright 1977.)

Animal Disturbance and Harassment

O'Shea (1995) cites the following Endangered Species Act definition of wildlife harassment: "An intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, feeding or sheltering." Although intentional harassment of wildlife does occur, the major impact is caused by recreationists who unknowingly and innocently produce stressful situations for wildlife (Fig. 2). The effects of photographers and bird-watchers who seek out the nesting areas of secluded species, backcountry campers who camp within critical watering and feeding habitats of large mammals, and off-road vehicle users who seek a closer look are but a few examples of unintentional forms of wildlife harassment. Of course, the chasing of winter-stressed wildlife by snowmobiles and certain forms of hunting are some extremes of intentional harassment. Harassment is such a common phenomenon in human-wildlife interactions that it has led some authors to state that there is no such thing as "nonconsumptive" use of activities concerning wildlife (Weeden 1976; Wilkes 1977). Wilkes rejects completely the concept that certain passive outdoor recreational activities are nonconsumptive and points out several impacts on wildlife by naturalists, photographers, and hikers. Wilkes even suggests the need for a skills test to be associated with the licensing of wildland recreationists because of the damage caused to wildlife resources by uninformed, unskilled people.

FIGURE 2. Recreationists unknowingly and innocently often produce stressful situations for wildlife. (*Photo*: Bruce C. Hastings.)

Many factors influence the effects or severity of harassment on animals. "Well-fed, healthy animals with ample refuges from disturbance can withstand more harassment than wildlife already under stress from severe weather, malnutrition, parasite loads, birth or nesting, or inadequate security areas" (Ream 1979, p. 153). Geist (1972, 1975) emphasizes the importance of physiological and psychological stresses to various wildlife, particularly bighorn sheep, and how stresses can compound the impacts of harassment. Although some species seem to habituate to the presence of humans, others are very stress-prone in regard to humans. The location of human-wildlife interactions is also a critical factor. The presence of people at key locations such as wolf dens, desert bighorn waterholes, snowfields used by caribou to escape heat and insects, ungulate migration routes, and salt licks may present major impacts (Ream 1979). Locational harassment impacts can be managed simply by protecting key areas from roads and trails, by locating campsites in appropriate areas, and by seasonally closing critical breeding habitats. Ream (1980, p. 7) suggests, "The primary targets of management should be critical times of the year and key locations of wildlife species vulnerable to harassment. Time and effort spent in alleviating harassment in other situations are wasted if habitat loss and wildlife mortality continue to occur at critical times and places."

The mere presence of people has been shown to be sufficient to cause harassment to some species whatever the recreational activity or number of people involved. Shore-nesting birds during the breeding season seem particularly susceptible to the presence of humans. The presence of even a few people inhibited the little tern (*Sterna albifrons*) in Great Britain from returning to its nest (Norman and Saunders, in Speight 1973). A survey of the breeding status of the species revealed a number of instances of breeding failure, apparently related to fishermen and sunbathers on the nesting beaches. Similar results have been reported for the ringed plover (*Charadrius hiaticula*). The red deer (*Cervis elephas*) of Europe and the bighorn sheep (*Ovis canadensis*) of the United States have also been observed to be sensitive to the presence of people. The situation may be more aggravated if people are wearing bright-colored clothing (Speight 1973).

The documentation of animal movement and behavior, including that related to human-caused disturbances, has been greatly aided by radio telemetry studies. Telemetry has commonly been used to determine location and movement of radioed animals. It is now possible to distinguish feeding, resting or rumination, and walking activity in elk (Ward, Cupal, Lea, Oakley, and Weeks 1973). Johnson and Pelton (1979) have used telemetry to study the denning behavior of the black bear in Great Smoky Mountains National Park. Black bears have been shown to enter winter dens 31 days earlier in areas with high levels of outdoor recreation; moreover, the bears were more likely to abandon dens when disturbed (Goodrich and Berger, in Knight and Cole 1995). Heart-rate telemetry is also used to determine the reaction of big game to disturbance by vehicles, recreationists, livestock, and other wildlife (Ward 1977). Future use of telemetry will allow scientists to measure alarm or harassment through increased heart rate of running animals as well as in animals in which the

flight reaction is inhibited. It can also be used to estimate energy expenditures and time required to recover from exertion, and to facilitate testing of methods to mitigate fear and stress (Ream 1979).

Harvest

Although harassment may produce a considerable amount of stress on wildlife and may even lead to the death of individual animals, such stress is second to that produced by recreational hunting, fishing, and trapping. Entire populations of wildlife in heavily hunted and fished areas are influenced by these recreational activities (Small, Holzwart, and Rusch 1991). In addition, certain types of hunting with dogs and particular types of trapping may lead to additional stress beyond that caused by the normal processes of harvesting wildlife. Martinka (1979) stated that many wild animals display the ability to differentiate various human activities and react more intensively to those perceived as threats to their life, based on past experience. Comparative studies of hunted versus nonhunted animals show that hunted wildlife are especially sensitive to humans during hunting seasons and tend to retreat from most forms of recreational activity at these times (Wood 1993).

Knight and Cole (1995) review additional responses of wildlife to hunting. The reproduction behavior of elk in Colorado appears to have been influenced by heavy hunting pressure. The conception dates of female elk showed a bimodal distribution, coinciding with hunting season dates. Other studies show that hunted animals often feed at night, returning to diurnal feeding only after hunting ceases. The spatial and temporal patterns of waterfowl are particularly sensitive to hunting. Hunted geese were six times more prevalent in a field on a day when shooting had not occurred during the previous afternoon.

History has documented the elimination or near elimination of many game species, including the passenger pigeon, beaver, bison, and other big game species. However, it was market and subsistence hunting in the context of reduced and fragmented habitat rather than recreational hunting that primarily led to the removal of these species. Recreational hunting, fishing, and trapping may eliminate a species on a local basis, but it is unlikely that these activities alone could directly result in the extinction of wildlife species.

Recreational activities directly associated with the harvesting of animals can lead to three major changes in the size of wildlife populations that, in turn, affect the quality of these recreational activities. These changes are (1) near elimination of a game species on a local level, (2) reduction beyond a viable breeding population, and (3) reduction beyond a viable hunting or fishing population. In the first instance, heavy hunting and fishing pressures on local populations of wildlife can locally extirpate certain species. The strong tradition of raccoon hunting and year-round training of raccoon dogs in the southern Appalachian Mountains of East Tennessee has caused the near extirpation of this animal in several counties. Similarly, the traditional hunting of black bear in the southern Appalachians has eliminated the species from many local areas. Second, harvesting of wildlife may not extirpate a population,

but it may reduce the number or sex ratio of individuals to such low numbers that the population can no longer breed successfully. Again, habitat loss is typically involved with harvest when this occurs. Finally, a population may have sufficient numbers to maintain a viable breeding unit but lack an adequate surplus to provide a rewarding harvest yield to the majority of hunters and fishermen. Of course, wildlife management agencies have the ability to regulate and manage all three of these situations.

Habitat Modification

For every animal species affected directly by wildland recreational activities, many more must be affected indirectly by modification of habitat (Cole and Landres 1995). Habitat change can affect the behavior, distribution, survivorship, and reproductive ability of individual wildlife. Impacts also occur at the population, community, and ecosystem levels over long time periods. Habitat modification is the primary impact of humans on insect, amphibian, reptile, bird, and small mammal populations. Soil organisms have been shown to decrease by up to a hundredfold in compacted soils and under snowmobile trails. Mice, voles, and shrews depend on the insulating properties of snow, which are lost when snow is compacted by snowmobiling and other winter recreational activities (Stace-Smith 1975). Tunnels and burrows of certain species are collapsed by off-road vehicles, particularly on beach dunes and desert lands (Bury, Wendling, and McCool 1976). Over a 10-year study of off-road vehicle impacts at Dove Springs within the California Desert, Berry (1973) documented loss of the desert tortoise, a protected and threatened species, and a reduction in both the density and diversity of small mammals and lizard populations. Not only do the tires of dune buggies cause physical damage to animals through the collapse of animal burrows, but they also eliminate their means of escape from extreme desert temperatures and desiccation.

In campgrounds, removal of shrubs and hazardous trees eliminates sources of food and shelter for birds and small mammals (Webb 1968). Blakesley and Reese (1988) report that seven bird species were associated with campgrounds while a different seven species were common to non-campgrounds. In improving or creating aquatic recreational sites, the removal of large quantities of shallow-water vegetation is responsible for loss of spawning grounds for freshwater fish. Sedimentation, pollution, and eutrophication of lakes by recreational homes and activities that modify the habitat of many species are common in many recreational areas.

Although recreational activities cause primarily a negative impact on wildlife habitat, there are several examples of habitat gain as a result of wildland recreation. Speight (1973) summarized these, including (1) the increased availability of nesting sites for mallards and wood ducks and over-wintering sites for species that use open water lakes and reservoirs developed for recreation, (2) increased food source as a result of organic litter left around campsites and picnic areas and the planned food plots of wildlife management agencies, (3) habitat changes and population localization of bear and wild boar as a result of campground rubbish dumpsites, and (4) creation of habitat for ecotone species as a result of trail, campsite, and pond development.

From his review of the literature, Speight (1973, p. 19) summarized the effects of recreation on habitat modification as follows:

> Increasing intensities of recreation use would seem to exert their most profound effects on microhabitats, by causing a progressive simplification of vegetation, ground surface, and soil structure. Invertebrate species particularly associated with soil or ground flora are in consequence perhaps more likely to be affected by trampling than vertebrates. In any event, the evidence suggests that a net decrease in animal species-diversity can be expected when an area is exposed to outdoor recreation, in parallel with any decrease in plant species-diversity that occurs, but offset to some extent by an influx of scavenging species. Species associated with ephemeral habitats such as bare ground might be expected to maintain their numbers or even increase in abundance at the expense of species associated with more stable ecosystem conditions like woodland.

Alteration of Behavior

The behavior of wild animals is often drastically altered by the frequent presence of humans. The behavioral changes can range from complete disappearance to slight modifications in habitat and daily use patterns to the habituation and taming of animals.

Habituation of wildlife in recreation areas is most often associated with food availability. Garbage dumps and litter at campsites have attracted bears, deer, birds, rodents, and insects, altering the natural feeding habits of these animals (Fig. 3). Skunks,

FIGURE 3. The natural feeding habits of animals are commonly altered by the availability of human food sources. (*Photo*: Jane Tate.)

chipmunks, and mice have become so dependent on human food sources at backcountry shelters and front country campsites that they are a nuisance in many U.S. national parks. The number of birds in Yosemite National Park, California was actually increased by the presence of campgrounds (Foin, Garton, Bowen, Everingham, Schultz, and Holton 1977). However, most of the increase was attributed to an abundance of a few species, especially Brewer's blackbird (*Euphagas cyanocephalus*) and the mountain chickadee (*Parus gambeli*). Clark's nutcracker (*Nucifraga columbiana*) and various species of jays have demonstrated a similar attraction to campsites and trails. At the same time, most other species decline in campgrounds.

Several other species have been shown to alter their behavior in response to recreational activities. Eagles and waterfowl have been documented as not returning to feeding sites until several hours after human disturbance (Anthony, Steidl, and McGarigal 1995), and large mammals have had their movement and feeding patterns modified by park traffic and roads. Singer, Otto, Tipton, and Hable (1981) found that average daily movement was greater for disturbed wild boars in Great Smoky Mountains National Park than for those with no disturbance. In another study Singer (1978) documented five possible responses of mountain goats to disturbances associated with highway crossings in Glacier National Park: (1) unsuccessful crossing attempts, (2) separation of nannies from kids, (3) alterations of crossing routes, (4) apparent alteration of crossing times, and (5) alteration of normal behavior and posture of goats. In Yellowstone National Park, when cross-country skiers approached within 400 m, elk moved an average of 1765 m to steep slopes nearer trees and often into another drainage area (Cassirer et al., in Knight and Cole 1995).

Species Displacement and Reproduction Level

Species displacement results in an animal being removed from a familiar environment and placed in a new habitat. Often, the replacement environment is of poorer quality or has more competing elements than the original area. Because of these factors, displacement is a more drastic change for wildlife than recreational harassment and habitat modification. The latter two impacts do not require that the animal move from a familiar environment. This may be a particular advantage in breeding success, inasmuch as familiar habitat and territory play a key role in wildlife reproduction. Although reproduction levels of wildlife are affected by most recreation-caused impacts, species displacement is likely to have the most drastic effects.

Species of wildlife that are secretive and sensitive to the presence of humans may become permanently displaced from recreational areas. Bighorn sheep and mountain goats have been forced into smaller areas and poorer, more remote ranges because of human encroachment. In Colorado bighorn sheep were forced into higher elevation ranges during lambing season, thus encountering weather conditions that caused an 80 percent incidence of pneumonia and a resultant decline in population (Woodward, Gutierrez, and Rutherford 1974). Batcheler (1968) found that red deer, when hunted and harassed in areas of good habitat, were displaced to poor habitat and did not return to the good habitat even after prolonged cessation of hunting and harassment.

In addition, deer displaced to the poorer habitat became nocturnal and experienced reduced reproductive rates and lower fat deposition.

Hunting and fishing have led to species reduction and displacement. Species eliminated locally by hunting and shooting tend to be predators at the end of food chains. Elimination or displacement of predators has an indirect effect on the population levels of other food chain members. In addition, the management of fish and game animals has resulted in some displacement impacts. In Great Smoky Mountains National Park, rainbow trout (*Salmo gairdnerii*), introduced in the early 1900s by loggers, have now out-competed the native brook trout (*Salvelinus fontinalis*) in many of the streams. Several other introductions of exotic species for recreational purposes have displaced original species, including native flora as well as native animals.

Hobby collecting of rare butterflies is the most important single factor contributing to the decline of two species of butterflies in Great Britain (Speight 1973). The British race of the large copper butterfly is extinct in Great Britain because of overcollecting. Certain plants like ginseng, orchids, and wild ramps have been displaced locally in many parts of the southern Appalachian Mountains because of hobby collecting and selling of the items.

Species Composition and Structure

The end result of the previously discussed impact parameters is an alteration of species composition and structure among wildlife populations (Anderson 1995). Gains, losses, and modification occur in both habitat and types of species. In general, the consequence of recreational activities in an area results in an overall decrease in species diversity in all trophic groups in all parts of the ecosystem (Speight 1973, p. 19). This follows a general decrease in structural differentiation of the ecosystem (i.e., loss of a proportion of the habitats present without their replacement by new habitats) and increase in the degree of resource sterilization (i.e., human simplification of site conditions). Certain populations of organisms increase as a consequence of recreational activities but usually at the expense of species diversity and richness.

IMPACTS ON WILDLIFE SPECIES

Large Mammals

Large mammals are mobile and difficult to study. However, three large animals that have received considerable attention are bears, bighorn sheep, and deer. Each represents a different type of major impact and set of management implications. For additional case studies concerning bald eagles, waterfowl, hawks, beach-area nesting birds, manatees, and rattlesnakes, see Knight and Gutzwiller (1995).

Black Bears. The black bear (*Ursus americanus*), because of its size, potential danger, and historical attraction to recreational sites, has been studied more than most other animals. The major impact problem with the bear is the alteration of its natural

behavior, more specifically, its habituation to human food sources. Black bears have learned to associate people and their camping equipment with food. This process is accelerated by the willingness of many recreationists to offer them handouts (Fig. 4). In Great Smoky Mountains National Park, 5 to 10 percent of these bears, euphemistically known as panhandlers, forsake their shy and secretive nature and soon begin to beg along roadsides, raid picnic tables, tear open coolers and backpacks, and break into vehicles and tents (Tate and Pelton 1983). Although panhandling behavior is not restricted to bears only, the size and strength of these animals make such encounters with people potentially dangerous. Singer and Bratton (1976) reported 107 incidents of human injury and 715 of property damage in Great Smoky Mountains National Park, Tennessee, in 1964 through 1976. Park records listed property damage at 83 incidents in 1977 and 189 in 1978, with injuries totaling 8 and 16 for those years, respectively (Tate and Pelton 1983).

Similar injury and property damage impacts have been recorded in Yosemite National Park, California (Table 1). Interactions between bears and humans have occurred in Yosemite since the 1920s, leading to alterations in natural behavior, foraging habits, distribution, and population levels (Keay and VanWagtendonk 1983). Bears in marginal natural habitats appear more dependent on visitor foods than bears in prime natural habitat. Keay and Van Wagtendonk also found a positive linear relationship between numbers of visitors and bear incidents, suggesting that visitor density reflects a level of food availability that attracts bears. After a certain level of

FIGURE 4. Panhandler bears in Great Smoky Mountains National Park visit backcountry shelters for food handouts. (*Photo*: Bruce C. Hastings.)

TABLE 1. Visitor Use, Reported Bear Incidents, and Property Damage Estimates for the Backcountry, Yosemite National Park, 1976–1979

Year	Visitors	Visitor Nights	Bear Incidents	Dollar Damage
1976	71,066	186,526	165	4,758
1977	74,537	194,243	371	9,397
1978	70,909	172,472	277	9,398
1979	66,053	181,775	225	8,553
Mean	70,641	183,754	260	8,027

Source: Keay and Van Wagtendonk 1983. Copyright © by International Association for Bear Research and Management.

bear-human interaction and/or food availability is reached, bears might more likely be drawn into a camp area and cause more incidents than in sparsely used zones. As a result of the high incidence of bear-human interactions in Yosemite, an intensive management program was initiated in 1975. The program included public information and education, removal of artificial food sources, enforcement of regulations, control of problem bears, and research and monitoring. From 1975 to 1979, this program resulted in decreases of bear incidents and property damage from 879 to 161 incidents, and from more than $100,000 to $13,000 in damages.

Habituating behaviors of black bears at a garbage dump was documented in Jasper National Park, Canada. At the park garbage dump bears exploited the resource by forming social aggregations, tolerating other bears at shorter distances when at the dump than when away (Herrero 1983). Social interactions between bears were characterized by tolerance, avoidance, and spacing. The dump was visited by 7500 to 10,000 park visitors during a 1968 study, and "despite hundreds of close approaches, including 57 situations in which people threw rocks or chased bears, a bear never struck, bit, or touched a person." Herrero observed that the average litter (2.67 offspring) was higher for bears that regularly visited the dump, suggesting that the food source contributed to reproductive success.

National parks that once contained open garbage dumps, and in some cases actually fed bears at the dump sites for public viewing, have now eliminated the dumps, forcing bears into natural feeding areas. Bear-proof trash cans in frontcountry campgrounds and the hanging of food out of the reach of bears in backcountry campgrounds have also decreased the incidence of bear-camper interactions. Although these management actions return bears to a dependence on natural food sources, there is evidence that in some instances the practice has decreased the reproductive success, health, and number of bears in certain populations.

The issue of roads and their effects on bear behavior has been addressed by a number of authors (i.e., Workshop on Bears and Roads, 10th International IBA Conference, Fairbanks, AK, 1995). Results range from bears being attracted to roads (i.e., roads used as travel corridors, particularly in habitat protected from hunting) to

roads being avoided (areas of heavy human use and hunting). Particular attention is now being directed toward identifying the characteristics (physical and biological) of corridors and strategic road crossing sites (Brody and Pelton 1989). Most of the previous work documented some impacts of roads on individual animals. How this translates to measurable population impacts is more speculative. However, Brandenburg (1996) reported on a small population of black bears that were nearly extirpated because of extensive road kills.

Bighorn Sheep. Bighorn sheep represent a different type of impact conflict. Human encroachment on bighorn habitat has contributed to displacement and a decline in sheep populations (Dunaway 1970). In the Sierra Nevada Mountains of California where recreational use is heavy, backcountry hiking disrupts the local migration and movement routes of bighorns. In areas heavily used by campers, hunters, or off-road vehicles, use of high-value habitat by bighorns can be excluded completely. Light (1971) found that bighorns tolerate only limited human disturbance before being driven from home ranges. Ewes with young were less tolerant of human approaches than individual ewes and rams.

Most observational studies have stressed the intolerance of bighorns to human encroachment, resulting in strict management policies on recreational use in some areas. However, the need for such policies is not exactly clear. Wehausen, Hicks, Garber, and Elder (1977) report that when zoological areas were established in the Sierra Nevadas to protect bighorns from assumed adverse effects of human disturbance, the results suggested that human disturbance was not as significant a factor as supposed. An eight-year study of sheep in Death Valley National Monument, Nevada, showed that only "unchecked human encroachment appears to actually threaten bighorns." Deliberate attempts of humans to conduct themselves within limits acceptable to bighorn sheep led to tolerance of human presence. Even though the limits and specific effects of human encroachment on bighorns are not completely understood, most resource managers are recommending that prompt conservation action should be taken, with the alternative in mind that management policy can be altered if the actions are proven unnecessary.

The monitoring of wildlife-road corridor interactions are a major concern in many recreation areas. This is particularly true in a wilderness-type park like Denali National Park in Alaska, where access to the park is by one major road. Between 1973 and 1983, there was a 50 percent increase in daily vehicular traffic on the main park road. This elevated volume correlated with a 72 percent decrease in moose sightings per trip and a 32 percent decrease in grizzly bear sightings (Singer and Beattie 1986). In the case of Dall sheep, Murie (1944) believed that the road enhanced predation on sheep by wolves because it provided easy access to winter range and escape cover, and blind corners provided opportunities for wolves to approach sheep without detection. More recent studies have shown that heavy bus and car traffic have blocked Dall sheep from moving across the road corridor and, in some instances, caused them to engage in running retreats from road activity (Dalle-Molle and Van Horn 1991). Current monitoring shows that the number of Dall sheep groups seen per

trip on the Denali road has declined from 4.6 in 1977 to 3.4 in 1982, 2.21 in 1995, and 2.32 in 1996.

White-Tailed Deer. In a survey of professional resource managers, the majority of respondents "felt that white-tailed deer were the most harassed species in their areas" (Huff, Savage, Urich, and Watlov 1972). Harassment and additional stress during winter months when deer are attempting to conserve metabolic energy are a major concern with winter recreational activities. Deer are naturally adapted to energy-conserving behaviors and mechanisms during snow seasons when range size is restricted. Energy conservation of up to 1000 Kcal/day for a 60 kg deer can result from reduced activity levels such as seeking level land, reducing snow depth, and walking slowly (Moen 1976). Winter harassment by hunting, snowmobiling, or skiing, whether intentional or not, is detrimental to the energy-conserving adaptations of deer. Moen, Whittemore, and Buxton (1981) reported that heart rate among captive deer in controlled tests increased an average of 2.5 times above normal rates when snowmobiles moved tangentially to the deer and 2.9 times above normal rates when circling the deer.

Research on the displacement of deer by snowmobile traffic has been mixed in its findings. During a test of 10 radio-collared deer in Wisconsin, results indicated that the deer did not significantly increase or decrease the size of their home ranges during three weekends of snowmobiling. Noise from the snowmobiles seemed to have little effect; snowmobiles had to be within sight of the deer before the animals would move away. Although animals were displaced from the snowmobile trails, the displacement was very temporary. The deer returned to areas along trails within hours after snowmobiling ceased. The research also revealed that deer will change the location of home ranges markedly even if snowmobiles are not present (Bollinger, Rongstad, Soom, and Eckstein 1973).

Studies by Dorrance, Savage, and Huff (1975) in Minnesota indicate that deer in snowmobile use areas may become habituated to snowmobile traffic. Home range size, movement, and distance from radio-collared deer to the nearest trail increased with snowmobile activity at a wildlife management area where public snowmobiling was held constant, but remained unchanged at a state park where numbers of snowmobiles per day averaged 10 on weekdays and 195 on weekends. However, the number of deer seen immediately adjacent to trails decreased with snowmobile use in the state park (Fig. 5). The deer did return to areas along trails within hours after snowmobiling ceased. Dorrance Savage, and Huff (1975) hypothesized that the subtle movements away from trails by deer result in little impact to deer, except during severe winters on poor ranges. In sensitive areas where some deer change their home ranges to entirely different locations, the authors believe that these effects could cause changes in the animal's energy budget that could be detrimental, especially during severe winters.

Deer are capable of habituating to the presence of people and vehicles. Deer often remain close to men working with chain saws and heavy equipment and are often attracted to established snowmobile trails that make walking easier in deep snow and browse more available. Research has also indicated that deer in areas open to

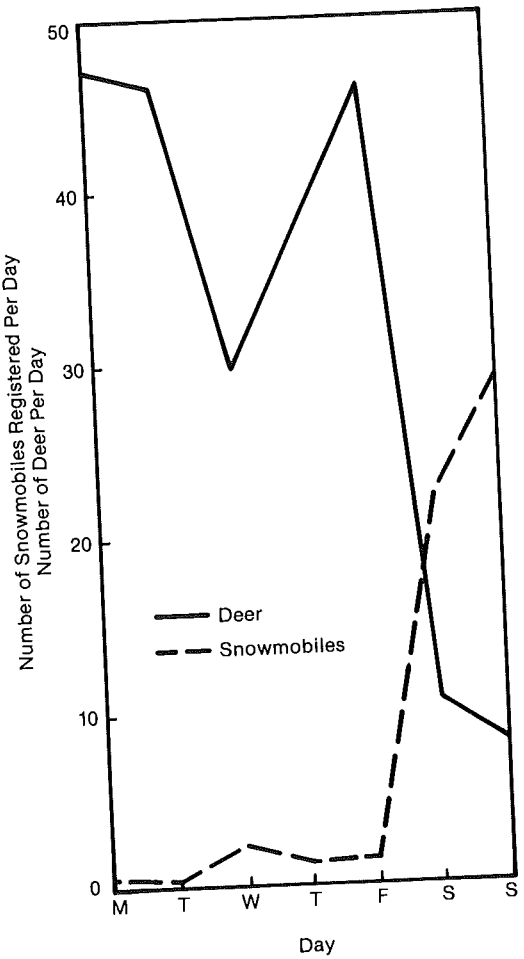

FIGURE 5. Mean number of deer observed per day, according to day of week, along a 10-km snowmobile trail in St. Croix State Park, Minnesota, 1973. (*Source:* Dorrance, M. J., P. J. Savage, and D. E. Huff, in *Journal of Wildlife Management*, Volume 39, Number 3, pp. 563–569. Copyright © 1975 by the Wildlife Society. Reprinted with permission.)

snowmobile use react initially to the machines, but further snowmobile traffic has little effect on their movement.

Other Ungulates. Although Nordic skiers cannot travel as far and as fast as snowmobiles, they can have similar adverse impacts on wildlife during the stressful winter months. Ferguson and Keith (1982) studied the influence of Nordic skiing on the distribution of moose and elk in a park in central Alberta. They found that elk and moose both tended to move away from ski trails. Significantly, movement away from trails was caused by the first skier encountered; the passage of additional skiers did not result in additional disturbance. Although there is little information on adverse

consequences of such movements on reproduction and survival, we do know that this increases the necessary caloric intake of these animals. Where food is limited, this could adversely affect the animals.

Medium-Sized Animals

Habituation to recreation-related food sources similar to that of black bears occurs among many medium-sized animals. Raccoons and skunks are common elements of many frontcountry campgrounds, particularly at night. Skunks in Great Smoky Mountain National Park have become so numerous and habituated to humans that they are common visitors during daylight hours, usually meandering through campsites. Local populations in these recreation areas increase rapidly, leading to population densities at which wildlife disease epidemics can be a serious problem.

Foxes and wolves show more avoidance toward recreationists. This is more true of wolves than red fox, as the latter has been shown to increase activity on and near snowmobile and snowshoe trails. This behavior may be a result of easier walking on the compacted snow or of the presence of cottontail rabbits, snowshoe hares, and other prey of fox that commonly use compacted snow trails. Wolves have been extensively studied in Isle Royale National Park, Michigan, because movement of the wolves is confined to the island and visitor use is heavy. Peterson (1977) found that wolf use of Isle Royale trails declines after visitors arrive in the spring. Selection of den and rendezvous sites indicates pronounced avoidance of humans. Management suggestions include limiting visitation, enlarging backcountry campsites rather than establishing new campgrounds, disallowing further trail development, and the assessment of discouraging winter visitor use.

The impacts of snowmobiles on medium-sized animals is inconclusive. Snowshoe hares were observed to avoid snowmobile trails, but red foxes were more active near and in such trails (Neumann and Merriam 1972). Schmid (1971) also observed that red foxes and deer were commonly seen following snowmobile trails. Apparently, the animals penetrate the snow less in the tracks of snowmobiles and find it easier to travel in the tracks. Penetrometer readings and measurements of animal penetration in snow off trails indicate an increase of about 85 percent (Neumann and Merriam 1972).

The indirect impact on predator species such as foxes, wolves, coyotes, bobcats, owls, hawks, and eagles by lowering the population of small animals in snowmobile use areas is a concern that has not been investigated. Snowmobile activity can have a detrimental effect on the numbers of small mammals surviving under compacted snow cover.

Easier and accelerated harvesting of animals because of increasing access to remote areas by snowmobiles is a concern of resource managers. The overharvesting of beaver and other furbearers has been suggested but not conclusively documented (Malaher 1967; Usher 1972). There is also little evidence that the snowmobile is likely to lead to significantly increased hunting pressure on big game. This is not to say that the incidence of illegal hunting and harassment by snowmobiles is not a concern, but rather that the overharvesting of animals as a result of snowmobiles has little support.

The popularity of river recreation has presented new levels of impact on many water-based species. Floating on white-water and backcountry rivers has increased rapidly in the United States, increasing the incidence of human interaction with waterfowl, eagles, osprey, and similar species. On canoeing rivers and lakes where overnight camping is common, the impact on loon populations is a concern. Increasing use of loon nesting islands for camping by canoeists appears to be the primary cause of decrease in loon productivity in the Boundary Waters Canoe Area, Minnesota. Osprey in Minnesota were also observed to build nests farther from lake and river shores, presumably because of increased watercraft activity.

Small Animals

Because the niche and microhabits of small animals are small, the habitat of these species is susceptible to destruction during the improvement and alteration of recreation sites. Clearing of both terrestrial and aquatic vegetation eliminates herbs, shrubs, and trees, which serve as sources of food and shelter for birds and small mammals. At the same time, human food sources attract rodents and certain species of small mammals and birds. Surveys of the riparian zone of the Colorado River showed abnormally high and unhealthy populations of rock squirrels, resulting from feeding by hikers. Lizard populations, which utilize driftwood for shelter and foraging, were reduced through the reduction of driftwood, used for campfires.

The effects of campgrounds on rodents are alteration of the feeding behavior and an increase in the population density of opportunistic feeders such as wood rats and deer mice. Backcountry overnight shelters along the 2000-mi long Appalachian Trail receive heavy visitation at night by mice, requiring proper storage of backpacker food. The same is true for food storage during daylight hours because of chipmunks and ground squirrels. Similar results have been found for campgrounds in Canyonlands, Arches, and Yosemite National Parks.

The influence of recreation on birds has already been discussed to some extent. The major impacts to songbirds and small nongame species are related to modification of the structure of vegetation and harassment during nesting. However, the presence of vegetation changes, of humans, and of food debris in campgrounds leads to an increase in numbers among some bird species. Brewer's blackbird, the brown headed cowbird, and robins were significantly more abundant in campgrounds of Yosemite National Park, but Oregon juncos were less abundant than in surrounding areas (Garton, Hall, and Foin 1977).

Harassment during wildlife viewing and photographing is also becoming a major issue. Bird-watching is one of the most popular forms of nonconsumptive, wildlife recreation. However, balancing wildlife viewing with wildlife impacts is a growing concern. Of five different recreationist-user groups at a wildlife refuge in Florida, photographers were the most disruptive, as they were most likely to stop, leave their vehicles, and approach wildlife (Klein 1993).

The most dramatic impact on small animals is caused by off-road vehicles, particularly snowmobiles. The compaction of snow by snowmobiles causes a reduction or destruction of the subnivean space, resulting in a mechanical barrier to the move-

ment of small animals. The tunnels of these animals are collapsed and the feeding area greatly reduced. The compaction also reduces the insulating qualities of the snow, causing stress and death to small mammals through reduced temperatures (Schmid 1971). Schmid (1972) further documents the effects by stating:

> Experimental manipulation of a snowfield has shown that the winter mortality of small mammals is markedly increased under snowmobile compaction. We recovered none of 21 marked animals from the experimental plot, whereas 8 to 18 marked specimens were captured at least once on an adjacent control plot. (p. 37).

Fish

Fish are not commonly thought of as wildlife by the general public, yet the recreating public can be an impacting agent on this specific form of wildlife. Lakes and streams concentrate recreational activities both from a water-based and shore-based perspective, leading to concentrated levels of impact on aquatic organisms (Fig. 6). Unfortunately, recreational impacts on fish populations are not well documented. Anglers have been shown to decrease the presence and feeding of bald eagles and ravens.

Direct impacts in the form of displacement occur through removal by fishing and introduction of exotic game species. Wilderness camping at popular alpine lake areas have "fished out" some lakes and reduced populations to numbers where the native populations are hardly viable. Accelerated harvesting as a result of Off-Road Vehicle (ORV) and snowmobile access to remote lakes has been documented, with one report

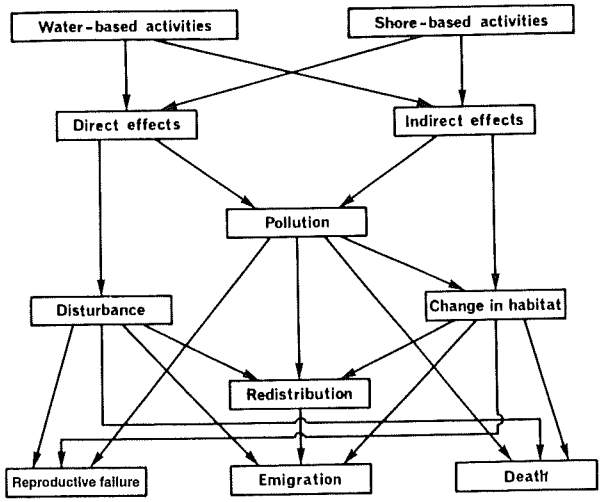

FIGURE 6. Impacts of water-based and shore-based recreation activities on wildlife. (*Source*: Liddle and Scorgie 1980.)

indicating 556 lbs of fish being harvested from a remote lake on a single winter day. "This would have been an entire season's catch if snowmobile access had not been possible" (Cooney and Preston, in Bury, Wendling, and McCool 1976). The introduction of rainbow trout to the streams of Great Smoky Mountains National Park by loggers before the area was designated a park has led to the displacement of the native brook trout from many of the streams. Fishing for the native brookies is no longer permitted in the park.

Most recreational impacts to fish result from indirect impacts to water quality and ecosystems. Eutrophication, pollution, and mechanical disturbance to aquatic vegetation as a result of wave action from boats all have the potential to disturb fish to varying degrees. Boating also contributes to increased turbidity, human-waste disposal, and the deposit of gasoline/oil mixtures on water surfaces. Concentrations of gasoline/oil mixtures have led to unacceptable levels of depleted oxygen supply for certain fish species and the off-flavoring of the flesh in fish.

SUMMARY

1. Different species of wildlife have different tolerances for interactions with humans. Even within a species, tolerance level for interactions will vary by time of year, breeding season, animal age, habitat type, and individual animal experience with recreationists.

2. Recreational impacts on wildlife may be *direct* or *indirect*. Direct impacts include the effects on animals by primary disturbances and interactions with humans. Indirect impacts are the secondary results of disturbance to habitat and other environmental parameters by recreationists. Larger game species are more affected by direct impacts and smaller species are more affected by indirect impacts of habitat modification.

3. The major impact to wildlife by recreationists is unintentional harassment, caused by individuals who unknowingly and innocently produce stressful situations for wildlife. Physiological and psychological stresses, particularly during winter, can greatly compound the severity of harassment impacts. The location and time of human-wildlife interactions are key elements in managing harassment impacts. Wildlife species vulnerable to harassment can be protected by protecting critical areas from roads and trails, by locating campsites in appropriate areas, and by seasonally closing critical breeding habitats.

4. The frequent presence of humans in wildland areas can alter the normal behavior of animals drastically. Slight modifications in habitat use and daily use patterns and the habituation and taming of animals are the most common behavioral changes. The availability of human food has led to altering the natural feeding habits of many animals in recreation areas.

5. In general, the consequence of recreational activities in an area results in an overall decrease in species diversity. A change in species composition and structure among wildlife populations is the ultimate result of human-wildlife interactions.

REFERENCES

Anderson, S. H. 1995. Recreation Disturbance and Wildlife Populations. In R. L. Knight and K. J. Gutzwiller, eds. *Wildlife and Recreationists*. Washington, DC: Island Press, pp. 157–168.

Anthony, R. G., R. J. Steidl, and K. McGarigal. 1995. Recreation and Bald Eagles in the Pacific Northwest. In R. L. Knight and K. J. Gutzwiller, eds. *Wildlife and Recreationists*. Washington, DC: Island Press, pp. 223–242.

Batcheler, C. L. 1968. Compensatory Responses of Artificially Controlled Mammal Populations. In *New Zealand Ecological Society Proceedings* 15:25–30.

Berry, J., ed. 1973. Preliminary Studies on the Effects of Off-road Vehicles on the Northwestern Mojave Desert: A Collection of Papers. Privately printed, Ridgecrest, CA. 100 pp.

Blakesley, J. A., and K. P. Reese. 1988. Avian Use of Campgrounds and Noncampground Sites in Riparian Zones. *Journal of Wildlife Management* 52:399–402.

Bollinger, J. G., O. J. Rongstad, A. Soom, and R. G. Eckstein. 1973. Snowmobile Noise Effects on Wildlife, 1972–1973 Report. Engineering Experiment Station, University of Wisconsin, Madison, WI. 85 pp.

Bowles, A. E. 1995. Responses of Wildlife to Noise. In R. L. Knight and K. J. Gutzwiller, eds. *Wildlife and Recreationists*. Washington, DC: Island Press, pp. 109–156.

Boyle, S. A., and F. B. Samson. 1985. Effects of Nonconsumptive Recreation on Wildlife: A Review. *Wildlife Society Bulletin* 13:110–116.

Brandenburg, D. M. 1996. Effects of Roads on Behavior and Survival of Black Bears in Coastal North Carolina. Master's thesis. University of Tennessee, Knoxville. 131 pp.

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.

Bury, R. L., R. C. Wendling, and S. F. McCool. 1976. Off-road Recreation Vehicles—A Research Summary, 1969–1975. Texas Agricultural Experiment Station, College Station, TX. Texas A & M University System. 84 pp.

Cole, D. N., and P. B. Landres. 1995. Indirect Effects of Recreationists on Wildlife. In R. L. Knight and K. J. Gutzwiller, eds. *Wildlife and Recreationists*. Washington, DC: Island Press, pp. 183–202.

Dalle-Molle, J., and J. Van Horn. 1991. Observation of Vehicle Traffic Interfering with Migration of Dall Sheep. *Ovis dalli dalli* in Denali National Park, Alaska. *Canadian Field Naturalist* 105:409–411.

Dorrance, M. J., P. J. Savage, and D. E. Huff. 1975. Effects of Snowmobiles on White-Tailed Deer. *Journal of Wildlife Management* 39:563–569.

Dunaway, D. J. 1970. Status of Bighorn Sheep Populations and Habitat Studies on the Inyo National Forest. *Transactions of Desert Bighorn Council* 14:127–146.

Ferguson, M. S. D., and L. B. Keith. 1982. Influence of Nordic Skiing on Distribution of Moose and Elk in Elk Island National Park, Alberta. *Canadian Field Naturalist* 96:69–78.

Foin, T. C., E. O. Garton, C. W. Bowen, J. M. Everingham, R. O. Schultz, and B. Holton, Jr. 1977. Quantitative Studies of Visitor Impacts on Environments of Yosemite National Park, California, and Their Implications for Park Management Policy. *Journal of Environmental Management* 5:1–22.

Fraser, D. F., and N. D. Eichhorn. 1969. Man and Nature in the National Parks: A Reflection on Policy. Conservation Foundation. Washington, DC.

Garton, E. O., B. Hall, and T. C. Foin, Jr. 1977. The Impact of a Campground on the Bird Community of a Lodgepole Pine Forest. In T. C. Foin, Jr., ed. *Visitor Impacts on National Parks: The Yosemite Ecological Impact Study*. University of California, Davis: Institute for Ecology. Publication No. 10. 99 pp.

Geist, V. 1972. On the Management of Large Mammals on National Parks. *Park News* 8(4):7–14, 8(5):16–24.

Geist, V. 1975. Mountain Sheep and Man in the Northern Wilds. Ithaca, NY: Cornell University Press. 248 pp.

Herrero, S. 1983. Social Behavior of Black Bears at a Garbage Dump in Jasper National Park. In E. C. Meslow, ed. *Bears—Their Biology and Management*. International Conference for Bear Research and Management 5:54–70.

Huff, D. E., P. J. Savage, D. L. Urich, and R. L. Watlov. 1972. Wildlife-Snowmobile Interaction Project—Preliminary Report. University of Minnesota and Minnesota Department of Natural Resources. 34 pp.

Johnson, K. G., and M. R. Pelton. 1979. Denning Behavior of Black Bears in the Great Smoky Mountains National Park. *Proceedings Annual Conference Southeastern Association of Fish and Wildlife Agencies* 33:239–249.

Keay, J. A., and J. W. VanWagtendonk. 1983. Effect of Yosemite Backcountry Use Levels on Incidents with Black Bears. In E. C. Meslow, ed. *Bears—Their Biology and Management*. International Conference for Bear Research and Management 5:307–311.

Klein, M. L. 1993. Waterbird Behavioral Responses to Human Disturbances. *Wildlife Society Bulletin* 21:31–39.

Knight, R. L., and D. N. Cole. 1995. Factors That Influence Wildlife Responses to Recreationists. In R. L. Knight and K. J. Gutzwiller, eds. *Wildlife and Recreationists*. Washington, DC: Island Press, pp. 71–80.

Knight, R. L., and K. J. Gutzwiller, eds. 1995. *Wildlife and Recreationists*. Washington, DC: Island Press. 372 pp.

Kuss, F. R., A. R. Graefe, and J. J. Vaske. 1984. Recreation Impacts and Carrying Capacity: A Review and Synthesis of Ecological and Social Research. Draft Review Report, University of Maryland, College Park, MD. 180 pp.

Kuss, F. R., A. R. Graefe, and J. J. Vaske. 1990. *Visitor Impact Management: A Review of Research*. Vol. 1. Washington, DC: National Parks and Conservation Association. 256 pp.

Liddle, M. J., and H. R. A. Scorgie. 1980. The Effects of Recreation on Freshwater Plants and Animals: A Review. *Biological Conservation* 17(2):183–206.

Light, J. T. R. 1971. An Ecological View of Bighorn Habitat on Mount San Antonio. *Transactions of the North American Wild Sheep Conference* 1:150–157.

Malaher, G. W. 1967. Improper Use of Snow Vehicles for Hunting. In Transactions, 32nd North American Wildlife and Natural Resources Conference. Wildlife Management Institute, Washington, DC. pp. 429–433.

Martinka, C. J. 1979. Measuring Effects of Human Presence on Wintering Wildlife in National Parks. In *Proceedings of the Second Conference on Scientific Research in the National Parks*. USDI National Park Service. San Francisco, CA. 6:199–211.

Moen, A. N. 1976. Energy Conservation by White-Tailed Deer in the Winter. *Ecology* 57(1):192–198.

Moen, A. N., S. Whittemore, and B. Buxton. 1981. Snowmobile Effects on Heart Rates of Captive White-Tailed Deer. Unpublished Paper. Department of Zoology. Auburn University, Auburn, AL. 18 pp.

Murie, A. 1944. *The Wolves of Mount McKinley*. Washington, DC: U.S. Government Printing Office. 235 pp.

Neumann, P. W., and H. G. Merriam. 1972. Ecological Effects of Snowmobiles. *Canadian Field Naturalist* 86:207–212.

O'Shea, T. J. 1995. Waterborne Recreation and the Florida Manatee. In R. L. Knight and K. J. Gutzwiller, eds. *Wildlife and Recreationists*. Washington, DC: Island Press, pp. 297–312.

Peterson, R. O. 1977. Management Implication of Wolf-Moose Research, Isle Royale National Park, Michigan. Report to the USDI National Park Service. Washington, DC. 14 pp.

Pomerantz, G. A., D. J. Decker, G. R. Goff, and K. G. Purdy. 1988. Assessing Impact of Recreation on Wildlife: A Classification Scheme. *Wildlife Society Bulletin* 16:58–62.

Ream, C. H. 1979. Human-Wildlife Conflicts in Backcountry: Possible Solutions. In R. Ittner, D. R. Potter, and J. K. Agee, eds. *Recreational Impacts on Wildlands*. USDA Forest Service Pacific Northwest Region, Seattle, WA, pp. 153–163.

Ream, C. H. 1980. Impacts of Backcountry Recreationists on Wildlife: An Annotated Bibliography. USDA Forest Service General Technical Report INT-81. 62 pp.

Schmid, W. D. 1971. Modification of the Subnivean Microclimate by Snowmobiles. In *Proceedings of Snow and Ice Symposium*. Cooperative Wildlife Research Unit, Iowa State University, Ames, IA, pp. 251–257.

Schmid, W. D. 1972. Snowmobile Activity, Subnivean Microclimate, and Winter Mortality of Small Mammals. *Bulletin of Ecological Society of America* 53(2):37.

Singer, F. J. 1978. Behavior of Mountain Goats in Relation to U.S. Highway 2, Glacier National Park, Montana. *Journal of Wildlife Management* 42(3):591–597.

Singer, F. J., and J. B. Beattie. 1986. The Controlled Traffic System and Associated Wildlife Responses in Denali National Park. *Arctic* 39:195–203

Singer, F. J., and S. P. Bratton. 1976. Black Bear Management in Great Smoky Mountains National Park. Uplands Field Research Laboratory Management Report No. 13. USDI National Park Service, Great Smoky Mountains National Park, Gatlinburg, TN. 34 pp.

Singer, F. J., D. K. Otto, A. R. Tipton, and C. P. Hable. 1981. Home Ranges, Movements, and Habitat Use of European Wild Boar in Tennessee. *Journal of Wildlife Management* 45(2):343–353.

Small, R. J., J. C. Holzwart, and D. H. Rusch. 1991. Predation and Hunting Mortality of Ruffed Grouse in Central Wisconsin. *Journal of Wildlife Management* 55:512–520.

Speight, M. C. D. 1973. Outdoor Recreation and Its Ecological Effects: A Bibliography and Review. Discussion Paper in Conservation 4, University College, London, 35 pp.

Stace-Smith, R. 1975. The Misuse of Snowmobiles Against Wildlife in Canada. *Nature Canada* 4:3–8.

Tate, J., and M. R. Pelton. 1983. Human-Bear Interactions in Great Smoky Mountains National Park. In E. C. Meslow, ed. *Bears—Their Biology and Management*. International Conference for Bear Research and Management 5:312–321.

Usher, R. J. 1972. Use of Snowmobiles for Trapping on Banks Island. *Arctic* 25:170–181.

Wall, G., and C. Wright. 1977. *The Environmental Impact of Outdoor Recreation*. Department of Geography Publication Series No. 11. University of Ontario, Waterloo. 69 pp.

Ward, A. L., 1977. The Effects of Highway Operation Practices and Facilities on Elk, Mule Deer, and Pronghorn Antelope. Project No. 942-41-42-13-0088-33 F2-6-2580. Annual Report of the Federal Highway Administration, Office of Research and Development. Washington, DC. 53 pp.

Ward, A. L., J. J. Cupal, A. L. Lea, C. A. Oakley, and R. W. Weeks. 1973. Elk Behavior in Relation to Cattle Grazing, Forest Recreation, and Traffic. *Transactions of the 38th North American Wildlife and Natural Resources Conference* 38:327–337.

Webb, W. L. 1968. Public Use of Forest Wildlife: Quantity and Quality Considerations. *Journal of Forestry* 66:106–110.

Weeden, R. 1976. Nonconsumptive Users: A Myth. *Alaskan Conservation Review* 27(9):3–15.

Wehausen, J. D., L. L. Hicks, D. P. Garber, and J. Elder. 1977. Bighorn Sheep Management in the Sierra Nevada. *Transactions of the Desert Bighorn Council* 21:30–32.

Wilkes, B. 1977. The Myth of the Nonconsumptive User. *Canadian Field Naturalist* 91(4):343–349.

Wood, A. K. 1993. Parallels Between Old-Growth Forests and Wildlife Population Management. *Wildlife Society Bulletin* 21:91–95.

Woodward, T. N., R. J. Gutierrez, and W. H. Rutherford. 1974. Bighorn Ram Production, Survival, and Mortality in Southcentral Colorado. *Journal of Wildlife Management* 38(4):771–774.

Workshop on Bears and Roads. 1995. 10th International IBA Conference, Fairbanks, AK.