

Effects of Recreational Activity on Wildlife in Wildlands

Richard L. Knight

*Department of Fishery and Wildlife Biology
Colorado State University
Fort Collins*

David N. Cole

*USDA Forest Service
Intermountain Research Station
Missoula, Montana*

Introduction

The primary goals of our designated wildlands—preservation of nature and provision of recreational opportunities—inevitably conflict. Consequently, managers are concerned with minimizing deleterious impacts of recreationists on those lands. Here, we address impacts on wildlife and attempt to summarize information about recreational impacts on wildlife. We propose a hierarchy of responses of wildlife to recreation and describe factors that influence the nature and magnitude of these responses. We draw conclusions concerning causal mechanisms, wildlife responses, factors which influence responses, and conclude with suggestions for necessary research.

Recreational Impacts and Wildlife Responses

Causes of Impacts

We suggest there are four ways by which recreational activities can impact animals—harvesting, habitat modification, pollution and disturbance (Figure 1). Harvesting wildlife has been purported to affect age and sex ratios, alter birth and death rates, influence behaviors, and alter habitat usage (e.g., Batcheler 1968, Douglas 1971).

Recreational activities can result in habitat modification by disturbing the vegetation and soil, and changing microclimates. Examples include trail and campsite development which results in alteration of vegetation, as well as changes in light and moisture conditions and topographic modification. Blakesley and Reese (1988) reported reductions in ground and shrub nesting birds in campsites due to habitat alterations.

Another way recreational activities alter wildlife is through pollution, such as people discarding food or deliberately feeding animals. For example, as bears become accustomed to food and garbage left by recreationists, their foraging ecology has been altered. An increase in bear-human encounters has resulted in the destruction of "problem" animals. As with habitat modification, few pollution-derived impacts have widescale impacts, other than when entire populations are affected (e.g., bears), or where uncommon habitats are being contaminated (e.g., caves).

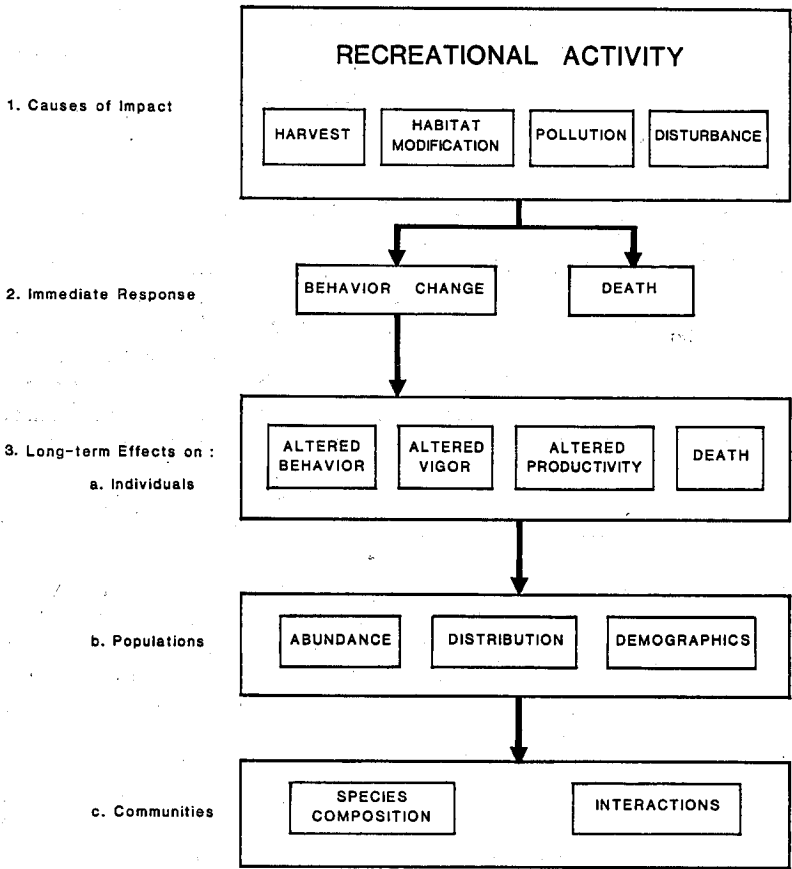


Figure 1 A conceptual model of responses of wildlife to recreational activities.

The final way that wildlife is affected by recreationists is disturbance. Disturbance can be intentional (i.e., harassment) or unintentional. Unintentional disturbance may include such things as attempting to photograph wildlife, naturalists viewing nesting birds, or hikers crossing an animal's territory. Unintentional disturbance is probably the primary means by which nonconsumptive recreational activities impact wildlife.

Immediate Responses

The most extreme immediate response of wildlife to recreational disturbance is death. Although this is the intended result of consumptive activities, nonconsumptive activities can also result in the death of animals. Snowmobiles crush small mammals that inhabit the subnivean space between snow and ground (Bury 1978), and off-road vehicles crush reptiles in the desert (Bury and Marlow 1973). Other than from consumptive activities, the direct death of wildlife is not highly significant.

The other type of immediate response is a change in behavior. All four causes of impact can alter behavior. Hunting results in waterfowl shifting their foraging pat-

terns; modified habitats may cause birds to alter their nesting behavior; littered campsites may cause chipmunks to change their food habits; and disturbance of grazing elk can result in elevated heart rates. Most of our understanding of disturbance is confined to the immediate behavioral responses of individuals to recreationists.

Long-term Effects on Individuals

Many of the responses of animals to disturbance are short-lived. For example, deer have been found to return within hours to areas they left when disturbed by snowmobiles (e.g., Dorrance et al. 1975). Immediate behavioral responses to disturbance, however, can become long-lasting changes, or behavior can slowly change to a new state. One behavioral change is abandonment of disturbed areas in favor of undisturbed sites. This response-avoidance scenario has been shown for a number of species, including caribou (*Rangifer tarandus*) and bighorn sheep (*Ovis canadensis*) (Geist 1978). Displacement into new environments can lead to a number of further behavioral changes, such as altered feeding ecology. The opposing response-attraction has also been documented. In this case animals are attracted to recreational disturbance. Usually attraction is a response to pollution (e.g., food waste) or habitat modification (e.g., caribou following the sound of chain saws to feed on downed trees [Klein 1971]).

Disturbance can also reduce the vigor of individuals and ultimately result in death. Elevated heart rates, energy expended in disturbance flights, and reduction of energy input through disturbance will all increase energy expenditures or decrease energy acquisition. These may result in increased sickness, disease and potentially death of individuals. While these responses have been suggested, evidence is largely circumstantial (e.g., Hutchins and Geist 1987).

There are numerous studies, albeit mainly on birds, which have documented decreased productivity in response to recreational disturbance. For example, the productivity of nesting common loons (*Gavia immer*) was negatively associated with the number of human contacts (Titus and VanDruff 1981). Experimental harassment of radio-collared mule deer (*Odocoileus hemionus*) by all-terrain vehicles resulted in reduced reproduction the following year (Yarnology et al. 1988).

Long-term Effects on Populations

Consumptive recreation activities can impact the abundance, distribution and demographics of populations. Sport hunting assumes that populations show compensatory responses. Batcheler (1968) found, however, that this did not occur with hunted populations of non-native red deer (*Cervus elaphus*) and chamois (*Rupicapra rupicapra*) in New Zealand, because populations were displaced to inferior habitat.

In contrast, we know very little about how nonconsumptive recreation affects population characteristics. We can only speculate that increased mortality, reduced productivity and displacement of populations (all documented, at least anecdotally) will result in decreased populations. Localized decreases in abundance have been reported for certain ground-nesting bird species in campgrounds (Blakesley and Reese 1988), and ungulates such as bighorn sheep (Dunaway 1970). Difficulties in establishing cause-and-effect make documentation of this response problematic. Information about the effects of nonconsumptive recreation on the demographics of populations is even more scarce.

Long-term Effects on Communities

Our knowledge on the impacts of recreationists on community structure is still rudimentary. Cole and Knight (1990) described how recreation could cause alterations in species diversity, depending on the severity of recreational disturbance and the spatial scale and level of the biological hierarchy for which diversity is being described. Skagen et al. (in press) showed that human disturbance would result in decreased species diversity in an avian scavenging-guild. Disturbance which resulted in altered feeding patterns by bald eagles (*Haliaeetus leucocephalus*) resulted in less available food for other scavengers. Eagles were the only scavenger present that could open the carcasses, and therefore make it available (unintentionally) for other species to feed on.

Factors that Influence Responses

Managers should attempt to keep wildlife impacts to acceptable levels by modifying the factors that influence the nature, frequency and magnitude of responses. This means either controlling recreational disturbance or influencing characteristics of the animals that will increase their tolerance to disturbance.

Characteristics of the Disturbance

Type of activity. As noted in the previous section, different activities may elicit different responses. For example, motorized boating in Minnesota resulted in nest desertion by common loons, whereas the presence of canoe travelers did not (Titus and VanDruff 1981). Different types of recreational activities, however, may not always have different impacts. The presence of a bird watcher along a shoreline may have the same effect as an angler fishing from shore. The context in which a particular activity occurs may also influence wildlife response. For example, sound elicits a much milder response from wildlife if animals are visually buffered from the disturbance (e.g., Singer 1978).

Recreational activities should not be viewed in isolation. There may be synergisms or interactions when more than one recreational activity is occurring simultaneously. For example, at a reservoir in South Wales sailing was not detrimental to waterfowl because boats used only the deep water areas and waterfowl used shallows. When bank fishing occurred, however, waterfowl moved to the deeper central waters where they then encountered sailors. Angling and sailing, therefore, resulted in birds being deprived of any part of the reservoir (Bell and Austin 1985).

Timing. Disturbance at any time of the year can affect an animal's inclusive fitness. Disturbance during the breeding season may affect an individual's productivity while disturbance outside of the breeding season may affect the individual's ability to forge and, therefore, its survival.

The most common response to severe disturbance during the breeding season is nest or young abandonment, which can lead to total reproductive failure (e.g., White and Thurow 1985). Disturbance during the breeding season can have different affects based on when during the reproductive phenology it occurs. For example, some researchers have attributed lowered reproduction in nesting ospreys (*Pandion haliaetus*) to human disturbance (e.g., Swenson 1979), while others (e.g., Poole 1981)

found no relationship between disturbance and nesting success. Disturbance during the incubation period resulted in greater reproductive failure than disturbance during the nestling period.

Disturbance can cause adults to temporarily leave their nest or den sites. Reduced parental attentiveness can increase the risk of young being preyed upon, disrupt feeding patterns, or expose young to adverse environmental conditions. If parents are disturbed from their nests, and are reluctant to return, then predators may visit the nest and consume eggs or young (e.g., Verbeek 1982).

Outside of the breeding season animals are not restrained to a nest or den site, nor are young as dependent upon their parents. Wildlife, however, still respond to disturbance, thereby potentially reducing energy acquisition (i.e., foraging) or increasing energy expenditure (i.e., fleeing) (Owens 1977, Stalmaster 1983). Stalmaster (1983) prepared an energetics simulation model which quantified the effects of recreationists on wintering bald eagles in the Pacific Northwest. His model predicted that land- and water-based disturbances that resulted in avoidance flights cost eagles 0.0359 kcal and 0.359 kcal, respectively. If 30 land and water activities occurred daily at a winter feeding site for 30 days while 300 eagles were present, 106,623 kcal would be expended in human-disturbance related avoidance flights, thus reducing the area's carrying capacity by 217 eagle days.

Location. The spatial context in which disturbance occurs can influence the response shown by wildlife because of the degree of threat or security posed by the spatial arrangement. For example, bighorn sheep showed stronger reactions to hikers approaching from above than to hikers approaching from below (Hicks and Elder 1979). Animals also appear to feel safer when they have greater open distance between themselves and potential threats. Pink-footed geese (*Anser brachyrhynchus*) in Denmark avoided areas where vegetation or topography hindered their views (Madsen 1985).

Frequency. The number of disturbance bouts that occur during a time interval can influence wildlife responses. For example, birds whose nests were visited frequently had lower reproductive success than those visited infrequently (e.g., Bunnell et al. 1981). There appear to be thresholds of disturbance frequencies where measurable wildlife responses occur. Recreation intensity values between 7.8 and 37.0 visitors ha^{-1} resulted in decreased bird densities in the Netherlands (van der Zande and Vos 1984). Belanger and Bedard (1989) found that when disturbance exceeded 2.0/hr, it resulted in a 50 percent drop in the mean number of snow geese (*Chen caerulescens*) present the following day.

Predictability. When disturbance is predictable and benign, it causes little response. Chamois appeared to habituate to humans as long as the intruders' activities remained spatially and temporally predictable (Hamr 1988). Disturbance which is threatening (e.g., active persecution), albeit predictable, would result in a different type of response from wildlife. For example, the level of wariness of a flock of birds feeding in a particular area depends on the tradition of disturbance in that area (Owen 1972, Knight and Knight 1986, Madsen 1988).

Characteristics of the wildlife being disturbed. The number and composition of wildlife groups may influence the response to disturbance. For example, animals feeding in groups respond to approaching threats at greater distances than solitary individuals (e.g., Owens 1977, Madsen 1985). These variations in flight distances are due to differences in tolerance among flock members. There is an increased likelihood that larger groups will contain individuals who are more sensitized to humans and will flee at a greater distance thereby causing other group members to also flee. Likewise, the time devoted to vigilance by feeding individuals decreases as flock or herd size increases (e.g., Caraco et al. 1980).

Age and sex of individuals may also influence wildlife responses to recreationists. For example, caribou cow/calf groups are more likely to flee than cow groups, and bulls are the least likely to frighten (Singer and Beattie 1986). Male chamois are more tolerant of disturbances than females, and females with kids escape sooner and withdraw further than yearling females or females without kids (Hamr 1988).

Wildlife response to disturbance also correlates with species' body size. Smaller species have both lower flushing responses and shorter flushing distances than larger species (Cooke 1980, Skagen et al. in press). This relationship has been attributed to both energetic considerations (e.g., surface area-to-body volume ratios) and persecution histories (e.g., larger animals more heavily persecuted than smaller animals; Knight 1984, Knight et al. 1989).

The nutritional state of an animal also influences its response. Researchers have suggested that malnourished individuals are less likely to flush, and flush at shorter distances than do individuals in good nutritional condition (e.g., Knight and Knight 1984, Hamr 1988). Processes influencing energy intake during winter have a much greater impact on energy balance of ungulates than processes affecting energy expenditure (Hobbs 1989). This suggests that disturbance which disrupts feeding wildlife should be of greater concern than disturbance which causes wildlife to flee.

Origin of Responses of Wildlife to Recreationists

Learned

A review of wildlife responses to human activities reveals an enormous amount of both intra and inter-specific variation. Peregrine falcons (*Falco peregrinus*) in New Mexico showed 22-fold differences in the distances at which they responded to similar stimuli (Johnson 1988). Suter and Jones (1981) reported 45-fold differences in flushing distances among three raptor species. Moose (*Alces alces*) in Denali National Park were more alert to vehicle traffic than were caribou (Singer and Beattie 1986).

This variation in intra- and inter-specific responses to disturbance has both innate and learned components. The learned component has been attributed to the number and outcome of interactions between individuals and stimuli over the individual's lifetime (e.g., Knight and Temple 1986a). King and Workman (1986) felt that desert bighorn sheep increased their avoidance responses to human beings with an increasing number of negative encounters. Three species of songbirds whose nests were repeatedly visited by researchers became significantly more aggressive over time (Knight and Temple 1986a, 1986b). Parent birds at nests visited only once, but at equivalent time periods during the nesting season, did not show elevated levels of aggressiveness.

Geese show increased wariness with an increase in harassment (Owens 1977, Madsen 1985).

Three categories of learned responses wildlife show to recreationists are avoidance, attraction and habituation. Habituation is defined as a waning of a response to a repeated stimulus which is not associated with either a positive or negative reward. A positive reward would result in attraction, whereas, a negative stimulus would result in avoidance (Eibl-Eibesfeldt 1970).

Knight et al. (1987) took advantage of a natural experiment to see whether American crows (*Corvus brachyrhynchus*) habituated to humans in an area of high human density and low persecution (i.e., cities). They hypothesized that in the absence of persecution, but in the presence of high human activity, crows would have to habituate in order to complete their daily activities. They compared the responses to crows to humans on the ground both in a city and in a rural area, where crows were actively persecuted. Crows in the city ignored humans on the ground indicating they had habituated to nonthreatening activities, whereas rural crows showed strong avoidance behavior.

Attraction is when an individual seeks out human beings because of rewards or positive reinforcement. Attraction may alter some important aspect of the animal's behavior, such as foraging, which could alter the animal's survival. Until the early 1970s, a portion of the grizzly bears (*Ursus arctos*) in Yellowstone National Park subsisted, to varying degrees, on human food wastes at garbage dumps within the park. Following the sudden closures of the dumps there were expansions in the size of bear home ranges, and decreases in body size, reproductive rate and average litter size (Despain et al. 1986). The change in nutrition from human food wastes to natural foods may explain a number of these life-history differences. In addition, bears had to relearn skills required to obtain live prey and carrion.

At the extreme view of this argument, there is the possibility that altered behavior of a keystone species could even alter an ecosystems. Tomback and Taylor (1986) studied Clark's nutcrackers (*Nucifraga columbiana*) at scenic turnouts in Rocky Mountain National Park where nutcrackers gather to feed on food provided by tourists. Nutcrackers are an important dispersal agent for limber pine (*Pinus flexilis*), a common species in the subalpine ecosystems of the Front Range of Colorado. If tourist activities discouraged normal nutcracker seed harvesting and storing activities, and altered the distribution of free-ranging individuals, then a decline in afforestation rates is possible.

Whereas animals might be expected to habituate to a benign stimulus, or be attracted to one with a reward, they should learn to avoid a stimulus associated with pain or punishment. Grizzly bears in Glacier National Park moved away immediately from people only 5 percent of the time, whereas, in a nearby area where they were persecuted, bears always moved away immediately, and on most occasions, they fled >1 km (McLellan and Shackleton 1989). Both common ravens (*Corvus corax*) and American crows nesting in areas of high persecution were more timid and showed stronger avoidance behavior and lower nest defense than birds in areas of low persecution (Knight 1984, Knight et al. 1987).

Genetic

In addition to learning, animals have a genetic component affecting their responses to stimuli. Animals are genetically predisposed to certain behaviors which are in turn

influenced by environmental factors (Hailman 1967, 1969). For example, bighorn sheep and mountain goats (*Oreamnos americanus*) withdrew to cliffs when they heard sudden loud noises, apparently an innate response to avalanches and rockfalls (Geist 1971, 1978). This genetically determined behavior can be reinforced through learning by the discharge of firearms in a hunted population.

Newton (1979) hypothesized that intraspecific differences in nest-defense behavior of Falconiformes were due to past levels of human persecution. If shooting disproportionately eliminated aggressive birds, then nest-defense aggressiveness would vary with the history of persecution in an area. Newton implied that natural selection was the mechanism that modified a species' behavior. Knight et al. (1989) compared nest-defense behavior in seven widely separated populations of red-tailed hawks (*Buteo jamaicensis*) in North America that differed in the number of years since European settlement (range: 75–215 years). Length of European settlement was assumed to correlate positively with the duration of active persecution. Birds in areas settled the longest were the most timid to human intruders suggesting a genetic component to their behavior.

Conclusions

Given the present state of our knowledge, there are gaps in our information which are readily apparent and that can be resolved only through well-designed studies which examine wildlife at different hierarchical scales. For example, we need to understand how recreation activities affect the inclusive fitness of individuals, and, in turn, whether populations and communities are impacted. If animals are denied access to areas that are essential for reproduction and survival, then that population will decline. Likewise, if animals are disturbed while performing essential behaviors, such as foraging or breeding, that population will also likely decline. If recreational disturbance does alter animal populations, then one must assume this response may alter the dynamics of a wildlife community. Accordingly, research on community structure and the role of recreational disturbance may yield some potentially important findings regarding the overall health of ecosystems.

There is an overwhelming need for studies which document the learning and decay rate of attraction, habituation and avoidance behaviors in animals. Ideally, these studies should be conducted on a variety of species which offer the full diversity of life-history strategies. Likewise, we need a better understanding of how the behavior of recreationsists influences the predictability and perceived threat of these activities to wildlife. This information would allow human management that promoted habituation by wildlife, which would, in turn, decrease negative impacts.

What happens to wildlife following disturbance? Since wildlife will not readily habituate to all types of recreation, where do animals go following disturbance? This question relates to both energy acquisition and habitat use. Are individuals able to compensate for lost foraging opportunities? What are the implications of crowding of individuals into remaining habitat if recreation causes previously suitable habitat to become unacceptable?

The pressures of recreational activities on wildlife in wildlands will not soon diminish. Responsible wildland management necessitates that we fully understand the numerous dimensions of recreation and wildlife. Although progress in this field to date has been slow, we are beginning to develop a conceptual model of the

interrelationships between the two and can anticipate rapid conceptual advances in the years to come.

References

- Batcheler, C. L. 1968. Compensatory response of artificially controlled mammal populations. *Proc. New Zealand Ecol. Soc.* 15:25-30.
- Belanger, L. and J. Bedard. 1989. Responses to staging greater snow geese to human disturbance. *J. Wildl. Manage.* 53:713-719.
- Bell, D. V. and L. W. Austin. 1985. The game-fishing season and its effects on overwintering wildfowl. *Biol. Conserv.* 33:65-80.
- Blakesley, J. A. and K. P. Reese. 1988. Avian use of campground and noncampground sites in riparian zones. *J. Wildl. Manage.* 52:399-402.
- Bunnell, F. L., D. Dunbar, L. Koza, and G. Ryder. 1981. Effects of disturbance on the productivity and numbers of white pelicans in British Columbia—observations and models. *Colonial Waterbirds* 4:2-11.
- Bury, R. L. 1978. Impacts of snowmobiles on wildlife. *Trans. North Am. Wildl. and Nat. Resour. Conf.* 43:149-156.
- Bury, R. B. and R. W. Marlow. 1973. The desert tortoise: Will it survive? *Natl. Parks Conserv. Mag.* 47(6):9-12.
- Caraco, T., S. Martindale, and H. R. Pulliam. 1980. Avian time budgets and distance to cover. *Auk* 97:872-875.
- Cole, D. N. and R. L. Knight. 1990. Impacts of recreation on biodiversity in wilderness. Pages 33-40 in *Proceedings of a Symposium on Wilderness Areas: Their Impact*. Utah State University, Logan.
- Cooke, A. S. 1980. Observations on how close certain passerine species will tolerate an approaching human in rural and suburban areas. *Biol. Conserv.* 18:85-88.
- Despain, D., D. Houston, M. Meagher, and P. Schullery. 1986. *Wildlife in transition: Man and nature on Yellowstone's northern range*. Roberts Rinehart, Inc., Boulder, Colorado. 142pp.
- Dorrance, M. J., P. J. Savage, and D. E. Huff. 1975. Effects of snowmobiles on white-tailed deer. *J. Wildl. Manage.* 39:563-569.
- Douglas, M. J. W. 1971. Behaviour responses of red deer and chamois to cessation of hunting. *New Zealand J. Sci.* 6:507-518.
- Dunaway, D. J. 1970. Status of bighorn sheep populations and habitat studies on the Inyo National Forest. *Trans. Desert Bighorn Council.* 14:127-146.
- Eibesfeldt, I. 1970. *Ethology*. Holt, Rinehart and Winston, New York, N.Y. 530pp.
- Geist, V. 1971. Mountain sheep, a study in behavior and evolution. Univ. Chicago Press, Ill. 383pp.
- . 1978. Behavior. Pages 283-296 in J. L. Schmidt and D. L. Gilbert, eds., *Big game of North America: Ecology and management*. Stackpole Books, Harrisburg, Pennsylvania.
- Hailman, J. P. 1967. The ontogeny of an instinct. *Behaviour Suppl.* 15:1-159.
- . 1969. How an instinct is learned. *Sci. Amer.* 221:98-108.
- Hamr, J. 1988. Disturbance behaviour of chamois in an alpine tourist area of Austria. *Mountain Res. & Develop.* 8:65-73.
- Hicks, L. L. and J. M. Elder. 1979. Human disturbance of Sierra Nevada bighorn sheep. *J. Wildl. Manage.* 43:909-915.
- Hobbs, N. T. 1989. Linking energy balance to survival in mule deer: Development and test of a simulation model. *Wildl. Monogr.* 101. 39pp.
- Hutchins, M. and V. Geist. 1987. Behavioral considerations in the management of mountain-dwelling ungulates. *Mount. Res. Develop.* 7:135-144.
- Johnson, T. H. 1988. Responses of breeding peregrine falcons to human stimuli. Pages 301-305 in Glinski et al., eds., *Proceedings of the Southwest Raptor Management Symposium and Workshop*. Natl. Wildl. Fed., Washington, D.C.
- King, M. M. and G. W. Workman. 1986. Responses of desert bighorn sheep to human harassment: Management implications. *Trans. North Am. Wildl. and Nat. Resour. Conf.* 51:74-85.
- Klein, D. R. 1971. Reaction of reindeer to obstructions and disturbance. *Science* 173:393-398.
- Knight, R. L. 1984. Responses of nesting ravens to people in areas of different human densities. *Condor* 86:345-346.

- Knight, R. L., D. E. Andersen, M. J. Bechard, and N. V. Marr. 1989. Geographic variation in nest-defense behaviour of the red-tailed hawk *Buteo jamaicensis*. *Ibis* 131:22-26.
- Knight, R. L., D. J. Grout, and S. A. Temple. 1987. Nest defense behavior of the American crow in urban and rural areas. *Condor* 89:175-177.
- Knight, R. L. and S. K. Knight. 1984. Responses of wintering bald eagles to boating activity. *J. Wildl. Manage.* 48:999-1004.
- Knight, R. L. and S. A. Temple. 1986a. Why does intensity of avian nest defense increase during the nesting cycle? *Auk* 103:318-327.
- Knight, R. L. and S. A. Temple. 1986b. Nest defence in the American goldfinch. *Anim. Behav.* 34:887-897.
- Knight, S. K. and R. L. Knight. 1986. Vigilance patterns of bald eagles feeding in groups. *Auk* 103:263-272.
- Madsen, J. 1985. Impact of disturbance on field utilization of pink-footed geese in West Jutland, Denmark. *Biol. Conserv.* 33:53-63.
- . 1988. Autumn feeding ecology of herbivorous wildfowl in the Danish Wadden Sea, and impact of food supplies and shooting on movements. Comm. No. 217, Vildtbiologisk Station, Dalso, Denmark.
- McLellan, B. M. and D. M. Shackleton. 1989. Immediate reactions to grizzly bears to human activities. *Wildl. Soc. Bull.* 17:269-274.
- Newton, I. 1979. Population ecology of raptors. Buteo Books, Vermillion, SD.
- Owen, M. 1972. Some factors affecting food intake and selection in white-fronted geese. *J. Animal Ecol.* 41:79-92.
- Owens, N. W. 1977. Responses of wintering brent geese to human disturbance. *Wildfowl* 28:5-14.
- Poole, A. 1981. The effects of human disturbance on osprey reproductive success. *Col. Waterbirds* 4:20-27.
- Signer, F. J. 1978. Behavior of mountain goats in relation to U.S. Highway 2, Glacier National Park, Montana. *J. Wildl. Manage.* 42:591-597.
- Singer, F. J. and J. B. Beattie. 1986. The controlled traffic system and associated wildlife responses in Denali National Park. *Arctic* 39:195-203.
- Skagen, S. K., R. L. Knight, and G. H. Orians. In press. Disturbance of an avian scavenging guild. *Ecol. Applications*.
- Stalmaster, M. V. 1983. An energetics simulation model for managing wintering bald eagles. *J. Wildl. Manage.* 47:349-359.
- Suter, G. W. and J. Jones. 1981. Criteria for golden eagle, ferruginous hawk, and prairie falcon nest site protection. *Raptor Res.* 15:12-18.
- Swenson, J. E. 1979. Factors affecting status and reproduction of ospreys in Yellowstone National Park. *J. Wildl. Manage.* 43:595-601.
- Titus, J. R. and L. W. VanDruff. 1981. Response of the common loon to recreational pressure in the Boundary Waters Canoe Area, northeastern Minnesota. *Wildl. Monogr.* 79.
- Tomback, D. F. and C. L. Taylor. 1986. Tourist impact on Clark's nutcracker foraging activities in Rocky Mountain National Park. Pages 158-172 in F. J. Singer, ed., Proceedings of the fourth triennial conference on research in the National Parks and equivalent reserves. Colorado State University, Fort Collins.
- van der Zande, A. N. and P. Vos. 1984. Impact of a semi-experimental increase in recreation intensity on the densities of birds in groves and hedges on a lake shore in The Netherlands. *Biol. Conserv.* 30:237-259.
- Verbeek, N. A. M. 1982. Egg predation by northwestern crows: Its association with human and bald eagle activity. *Auk* 99:347-352.
- White, C. M. and T. L. Thurow. 1985. Reproduction of ferruginous hawks exposed to controlled disturbance. *Condor* 87:14-22.
- Yarmoly, C., M. Bayer, and V. Geist. 1988. Behavior responses and reproduction of mule deer, *Odocoileus hemionus*, does following experimental harassment with an All-terrain Vehicle. *Canadian Field-Natur.* 102:425-429.