

# ASSESSMENT AND MANAGEMENT OF WILDLAND RECREATIONAL DISTURBANCE

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## INTRODUCTION

Disturbance from wildland recreation is widespread, extending even to many remote and protected areas, and its effects have important ramifications for wildlife. Yet, many wildlife scientists and managers do not receive training to assess and manage this disturbance. Unlike many topics in this book, wildland recreation has not been a traditional subject of analysis or concern in wildlife curricula. Recreational activity and disturbance occurs in many natural areas near suburbs and cities, but wildlands typically are larger and more complex, provide more living space for wildlife, and are more likely to be managed by trained wildlife professionals. Thus, defining and characterizing wildland recreation, based on earlier literature (Flather and Cordell 1995, HaySmith and Hunt 1995, Hammitt and Cole 1998:3-5) and our experience, is where we begin.

*Wildland recreation* refers to nonwork outdoor activities that are conducted in natural environments. In contrast to activities in developed recreation areas (e.g., amusement parks, swimming pools, sports complexes), wildland recreation depends significantly on one or more of the natural resources (e.g., forests, water, wildlife) that occurs in a wild or undeveloped environment. Stated differently, in wildland recreation, a primary focus and source of motivation for activities is the natural setting itself or components thereof.

Although not all wildlands are wilderness, wildland recreation occurs in places where management seeks to sustain natural conditions. Consequently, facilities are

usually few in number, small in size, and designed primarily to improve visitor safety or to protect resources, not to entertain or comfort recreationists. Recreation occurs in undeveloped lands that are small and close to urban areas, but lands used for wildland recreation are typically isolated from dense human populations; roads, when present, are often of lower quality, and trails may not exist. In this chapter, we focus on recreational activities that occur in large remote wildlands. Within such areas, recreational use tends to occur in many different places. Most wildland recreation occurs on public lands, such as federal and state parks, refuges, forests, and grasslands, but some occurs on private lands.

Many wildland recreational activities depend directly on wildlife. *Wildlife-dependent activities* are pursued with the goal of encountering wildlife for some purpose (e.g., harvest, watch, photograph); wildlife is the primary motivator for participation. Other recreational activities are not contingent on wildlife. For these activities, wildlife may add enjoyment (e.g., watching wildlife), present risk and challenge (e.g., grizzly bears [*Ursus arctos*] near camping areas in Glacier National Park), or may be a nuisance (e.g., bears and rodents pilfering packs in Yosemite National Park), but participation does not depend primarily on wildlife occurrence because encounters with wildlife are incidental. Some wildlife-dependent activities (e.g., big-game and upland-game hunting) involve harvest and have been referred to as *consumptive*, whereas recreational activities that do not involve harvest have been referred to as *nonconsumptive*. The latter term can be misleading.

however, because significant disturbance from some non-hunting activities, including some that are not wildlife-dependent, can decrease wildlife reproduction and survival, causing these activities to be consumptive in their effects. This chapter emphasizes nonharvest activities. The chapter on harvest management in this volume (Connelly et al. 2005) addresses the effects of hunting on wildlife. Fishing can be consumptive, but fish are not typically considered wildlife. Consequently, we do not consider the extractive effects of angling on fisheries, but we do discuss wildland disturbance from fishing because the presence and movements of anglers may affect terrestrial and aquatic wildlife.

Recent analyses (Flather and Cordell 1995, Cordell and Super 2000), from which we derived the brief discussion that follows, trace the history of outdoor recreation development in the United States and forecast the wildland recreational activity we can expect in this country in the coming years. Outdoor recreation demand has grown since the late 1940s, when the post-World-War-II economy expanded and general affluence increased. During some or many of the last 5 decades, number of participants and days of participation increased for consumptive pursuits (fishing and big-game hunting) and nonconsumptive activities such as camping, backpacking, hiking, off-road vehicle driving, horseback riding, swimming in natural waters, boating, waterskiing, downhill and cross-country skiing, and snowmobiling. In recent years, some of the most dramatic increases in participation have occurred for nonconsumptive, wildlife-dependent activities, such as wildlife watching. In addition, relatively new activities, such as mountain biking, mountain climbing, rock climbing, caving, orienteering, rafting and tubing, and jet skiing have become increasingly popular.

Most wildland recreational activities are not wildlife-dependent, and participation (number of trips) in many of these activities is projected to increase substantially (Fig. 1). Wildlife managers should anticipate growth in wilderness use, rock climbing, white-water activities, caving, cross-country snow travel, and ice climbing. Participation (number of participants) in fishing and in wildlife-dependent activities that do not involve harvest (e.g., wildlife observation and photography) is expected to rise 63–142% during 1985–2040. For this same period, big-game hunting participation is predicted to change little, whereas small-game hunting participation is projected to decrease. Although disturbance from consumptive activities may stabilize or decline, nonconsumptive activities, which are frequently detrimental to wildlife (e.g., Boyle and Samson 1985), are on the rise. Thus, wildland managers should expect recreational disturbance of wildlife to continue to increase in intensity and geographic scope as demand for experiences in natural environments expands.

Disturbance from direct contact with recreationists has been linked to such effects as declines in reproduction, survival, and vigor; higher predation rates; increased vigilance at the expense of activities such as brooding of young and foraging; displacement from habitats that are needed for important life-history activities; and alteration of food habits (Boyle and Samson 1985, Burger 1995, Knight and Gutzwiller 1995, Joslin and Youmans 1999). Indirect effects are defined as those that arise through habitat (soil, vegetation, water) degradation by recreationists. They can

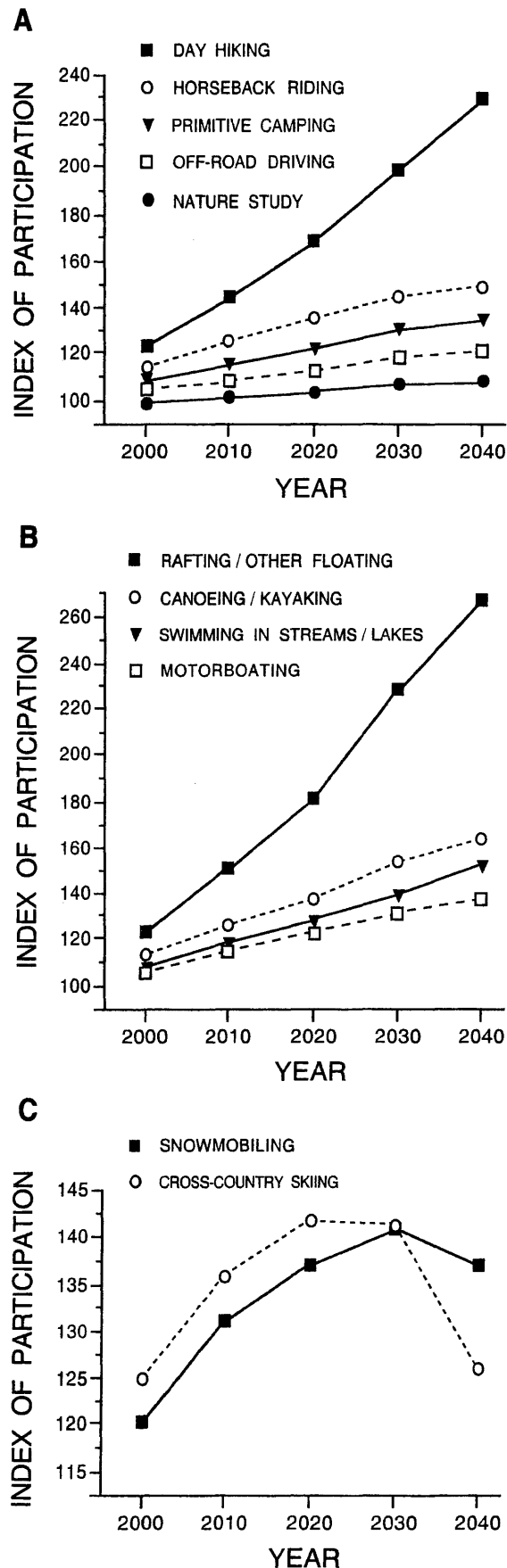


Fig. 1. Projected participation indices (growth in wildland recreation trips, 1987 = 100) for land- (A), water- (B), and snow-based (C) activities in the United States, 2000–40. Data are from Flather and Cordell (1995).

be just as problematic for wildlife as are direct effects (Cole and Landres 1995, Joslin and Youmans 1999). The effects of human disturbance in wildlands can vary among species, populations, and individuals (Knight and Temple 1995a) and with such factors as time of year (Hamr 1988, Götmark 1992), prior experience with humans (Knight and Fitzner 1985, Marzluff 1988), noise levels (Bowles 1995), speed of recreationist movement (Richens and Lavigne 1978, Burger 1981), location of recreationists (Herbert and Herbert 1965, Hicks and Elder 1979, MacArthur et al. 1982), and type of recreation (Burger 1995, Knight and Cole 1995a). Cumulative and synergistic effects of these influences also are possible (Bell and Austin 1985, Gutzwiller 1995). Clearly, the effects of recreation can depend on the specific set of circumstances involved; the consequences that develop for one set of conditions may or may not develop for others. Accordingly, assessment and management of recreational disturbance typically does not entail simply applying approaches used previously; instead, efforts must be tailored to a particular disturbance situation.

Land-management agencies operate under multiple mandates, including some that require provision of recreation opportunities; therefore, minimizing recreational disturbance to wildlife must usually be balanced with other goals. For example, the public derives substantial benefits from viewing wildlife, so management actions that drastically limit such activities may not be appropriate. Recreational disturbance of wildlife may not be severe enough to require restriction of recreation. In some situations, recreational activities have minimal negative effects on wildlife (Knight and Gutzwiller 1995). Many groups of wildland recreationists are among the strongest advocates for wildlife or the environment, and it is important that wildlife professionals not alienate these groups by acting on preconceived notions about the effects of their recreation. Thus, during assessment and management efforts, it is crucial that wildlife scientists remain objective about potential influences, and that wildlife managers carefully consider both the costs (wildlife disturbance) and benefits (public enjoyment and support) of providing recreational opportunities. We recommend that techniques described in this chapter be used to develop and implement a policy of coexistence—one that seeks a balance between wildlife protection and the provision of opportunities for recreation.

The need to assess and manage recreational disturbance is pressing because it is occurring on public and private wildlands, which are the most natural areas that remain for support of wildlife. This chapter discusses methods for assessing the nature and magnitude of recreational disturbance and for avoiding or reducing such disturbance. Specifically, we (1) describe how existing information can be used to evaluate the potential for harmful effects; (2) indicate how to conduct field studies to obtain new information; (3) present a framework for disturbance management based on objectives, monitoring, and effects of previous management actions; (4) provide options for managing recreationists, including approaches for informing visitors and regulating aspects of their activities; and (5) explain how to reduce recreational disturbance through wildland planning and management, with emphasis on facilities and infrastructure placement, and regulation of their use.

## ASSESSING EFFECTS OF RECREATIONAL DISTURBANCE ON WILDLIFE

Because some recreational disturbance of wildlife occurs on all wildlands, the potential severity of impacts should be assessed routinely. The nature of assessments will vary greatly, however, with such variables as management goals, available information, perceived threats, and available funding. All areas should assess impact potential. Most should conduct routine monitoring, and some should initiate field studies. As uncertainty about wildlife impacts mounts and the importance of wildlife conservation grows, managers increasingly face 2 choices—either conduct field studies of wildlife impact or err on the side of unnecessary restriction when managing recreational activity. Although field studies can be costly in the short-term, long-term costs are inevitably greater if wildlife is disturbed severely or recreationists are restricted needlessly.

## EVALUATION OF IMPACT POTENTIAL

The purpose of an evaluation is to use existing information (data, expert knowledge, and logical thinking) to identify wildlife species that may require unusual management emphasis. These may be species with special status (e.g., threatened and endangered species), game species, or species that are major attractions for recreationists. In addition, they may be species that are judged to be most vulnerable to substantial recreational disturbance in particular places and at certain times. Definitions of what constitutes high vulnerability and substantial disturbance are not absolute; they will vary from place to place. An assessment of the relative vulnerability of different species, places, and times is a means of prioritizing monitoring efforts and management techniques. If there is sufficient uncertainty about impacts, field studies are warranted.

The initial step in any evaluation of impact potential is to compile an inventory of species either known or likely to be in the area. The next step is to gather existing literature and expert opinion about likely impacts on these species. Joslin and Youmans (1999) provide an excellent example of the wealth of insight that can be gained by compiling existing information for Rocky Mountain wildlife in Montana. Their report highlights information about recreational effects on groups of animals, such as amphibians and reptiles, as well as on important individual species, such as wolverine (*Gulo gulo*) and Canada lynx (*Lynx canadensis*).

Species with special status should be identified first. The most obvious are species listed as endangered or threatened under the Endangered Species Act, those proposed for listing, or those identified as sensitive by the U. S. Forest Service, U. S. Bureau of Land Management, or state organizations. In most cases, recreation should be managed so that recreational disturbance of these species is negligible. These species will probably be the focus of most monitoring, most field studies, and much of the recreation management program. However, other species should not be ignored, particularly if their populations are vulnerable to significant recreational disturbance, they are important game species, or they attract the wildlife-viewing public.

Populations of rare species that have large home ranges or territories are often vulnerable simply because so few individuals exist. Loss of just a few individuals can have a substantial impact on the entire population. Field studies or monitoring of such species should be a priority. Many of these should already be on lists of species of special concern.

The species most vulnerable to recreational disturbance are those for which a substantial portion of the population is impacted by recreation and for which individual animals are profoundly affected by recreational disturbance. Particularly in large wildlands, the vast majority of species will probably not be impacted substantially by recreation because their populations are widespread, home ranges or territories are small, and recreational disturbance is often localized around the recreation site. For example, recreation will alter the behavior and food habits of individual chipmunks (*Tamias* spp.) that live close to trails or campsites. As undesirable as this is for these individuals, recreation may not substantially threaten chipmunk populations if only a small portion of a healthy and abundant population will be impacted. Most chipmunks will not come in contact with humans and will remain completely undisturbed by recreation. Many invertebrates, fish, amphibians, reptiles, birds, and small mammals may be in this category. If there is little potential for widespread impact, little effort needs to be expended on monitoring recreation impacts on these species unless the situation changes (e.g., increasing habitat fragmentation or development of adjacent lands). This does not mean there is no impact on these species. Nor does it mean that educational programs should not be developed to reduce impacts as much as possible.

Of the species with small home ranges or territories, the most vulnerable are those that are highly selective in the habitats they occupy. Even these species may not be highly vulnerable if there is little spatial overlap between wildlife habitat and recreational activities. Suitable habitat for selective species can be mapped, either on the basis of direct observation or from predictive models, and the information can be overlaid on maps of recreational use to identify potential areas of conflict or to suggest where trails and facilities should and should not be constructed. Given the attraction of recreationists to riparian strips (Blakesley and Reese 1988), species that occupy riparian zones are of particular concern in many places. Some species, such as invertebrates, reptiles, and amphibians, are concentrated and therefore more vulnerable at certain times of the year. Management of the timing of recreational activity can effectively limit impact on these species.

It is more difficult to generalize about impacts on species that are populous but that have large home ranges or territories. For these species, a substantial proportion of individuals in the population may come into conflict with recreationists even when recreational use is localized. These individuals have the capacity to learn from encounters with recreationists. Field studies or at least monitoring of such species is desirable. Severity of impact to such species is influenced by the nature of the learned response, along with the spatial pattern of recreational use and critical habitat. Populations in which most individuals learn strong avoidance behavior may be substantially impacted if recreational use is widely dispersed and/or occurs with-

in much of the preferred habitat for feeding, breeding, or birthing. Populations in which most individuals exhibit strong attraction responses also can be impacted significantly if the outcomes of encounters are often lethal, as is the case with black bears (*Ursus americanus*) (Singer and Bratton 1980).

## MONITORING

Routine monitoring should be a part of any management program. Both recreational use and wildlife populations of concern should be monitored. It is important to monitor recreational activity because most techniques for mitigating wildlife impact involve managing visitor use. The amount and type of recreational use, including how use is distributed in space and time, should be monitored. It would be efficient to focus monitoring of visitor use in places where wildlife species are highly concentrated or particularly vulnerable. Techniques for monitoring visitor use are varied and highly developed. Numerous devices are commercially available for measuring car traffic and flow through developed facilities. Monitoring dispersed travel, particularly foot travel in remote wildlands, is more challenging. Watson et al. (2000) provide a handbook on alternative techniques for estimating magnitude, type, and location of recreational use in wildlands; it includes practical information about establishing objectives, deciding what variables to monitor, designing and implementing a sampling plan, and calculating statistics that can be used to affect management decisions.

Techniques for monitoring wildlife populations also are diverse and well-developed. The high cost of monitoring populations makes it important to focus monitoring efforts carefully. The primary species on which to focus monitoring are threatened and endangered species, species of special concern, or species that are locally concentrated in space or at particular times of the year. Techniques for monitoring wildlife populations are covered at length in other chapters of this manual. Monitoring the effects of recreation on wildlife can be problematic because it is seldom possible to separate the effects of recreation from other influences on wildlife populations. Consequently, it is often necessary to conduct field studies to establish cause-and-effect relationships between recreation and wildlife and then to monitor recreation use carefully. Even if field studies have been conducted, it is still important to monitor wildlife populations. Moreover, if dramatic changes in management are undertaken, monitoring of wildlife populations can provide crucial information about the effectiveness of these actions.

## CONDUCTING FIELD STUDIES

When potential exists for significant recreational disturbance to wildlife, and when available information does not provide an adequate scientific basis for evaluating the actual effects of this disturbance, field studies should be conducted. These studies should attempt to evaluate factors that influence the nature and magnitude of impact and whether the activity is detrimental. This work is needed to verify suspected recreational impacts so that decisions about how to manage these activities are consistent with their real impact. If careful studies confirm that an activi-

ty with significant disturbance potential actually has negligible effects, restrictive management would not be necessary; indeed, regulation of recreation in this case would be indefensible and detrimental to relationships between recreationists and wildland managers. If field studies indicate that a recreational activity is substantially detrimental to wildlife, decisions must then be made about how to manage the activity so that wildlife impacts are not significant. Because of the context-specific nature of recreational impacts on wildlife, it is not wise to apply blindly a management technique that has been used previously for a similar problem. Differences between one's local situation and the situation in which the management technique was applied previously (e.g., the species, frequency of recreation, habitat conditions, historical context of human disturbance) may reduce or eliminate the method's effectiveness. Thus, in many cases, field studies may be needed not only to reveal actual impacts, but also to evaluate the success of a management approach.

### Field Study Type and Design

Experimental and non-experimental (observational or correlational) studies can shed light on recreational disturbance and how to manage it. Each of these 2 study types has advantages and disadvantages, and the decision about which type of study to conduct will be affected largely by the specific type of recreational disturbance in question, available resources (e.g., funding, personnel, time), and the need for information about cause-and-effect relations. An additional consideration is how the results of a study will be used to dictate management actions. For example, simple initial studies can be used to identify the factors on which more expensive, in-depth research should focus, but such pilot studies would not by themselves be rigorous enough to formulate management policy. Research approaches must be scientifically valid if one intends to use the results to direct management because inaccurate information may lead to mismanagement of wildlife or recreational activity, and because user groups may challenge management actions. Regardless of study type, the usual principles of sampling, replication, statistical power, study design, and data analysis must be applied. We do not discuss these principles because they are described in detail elsewhere (e.g., Green 1979, Hurlbert 1984, Cohen 1988, Hairston 1989, Hair et al. 1998, Zar 1999, and chapters in this volume).

### Experimental Studies

Lack of understanding about cause-and-effect relations is a significant impediment to managing recreational disturbance. The most credible, defensible, and efficient way to surmount this problem is to conduct properly designed experiments. In contrast to many other aspects of wildlife science, assessment of recreational disturbance lends itself quite well to experiments (Gutzwiller 1991). The reason is that human activity is the primary factor of interest, and we can often experimentally manipulate such activity (Yarmoloy et al. 1988, Skagen et al. 1991, Knight and Cole 1995a). In a recreational disturbance experiment, one manipulates the activity of concern to test a hypothesis about the effect of that activity on wildlife. Control units, in which no disturbance occurs, must be included so that one can separate the effects of other factors that vary

through space or time from the effects of changes in the activity of interest. Without controls in space and time, cause-and-effect relations cannot be established. Examples of units in recreational studies include sites (Gutzwiller et al. 1997), nests (Knight and Fitzner 1985), individual animals (Stalmaster and Newman 1978), and family groups (Keller 1991).

One experimental approach is to mimic recreational disturbance through use of investigators who conduct the recreational activity in question. The key advantage of this technique is that factors associated with recreationists, such as movements in time and space, noise levels, vehicle type, frequency of occurrence, and party size, can be controlled. The result can be a more precisely controlled and, hence, more interpretable experiment. However, such studies must ensure the simulated activity matches the actual recreational activity as closely as possible so the results are applicable to real-world situations (Gutzwiller 1991). In addition, if investigators are implementing recreation treatments as well as evaluating their effects, investigators must be blind to the hypotheses being tested (e.g., Gutzwiller et al. 2002) so preconceived notions about the influence of the disturbance do not bias their observations of effects. Using investigators to simulate recreational disturbance also requires funding for personnel, transportation, housing, and equipment needed to mimic the recreation, as well as development of specific treatment (disturbance) protocols (e.g., Gutzwiller and Anderson 1999). Depending on the activity and the spatial and temporal scales involved, costs of mimicking recreational disturbance can be high.

Another experimental approach is to assess recreational disturbance through serial management experiments (Macnab 1983, Gutzwiller 1993), an adaptive approach in which activities of actual recreationists are manipulated in time, space, or both through management actions. After each experiment, new knowledge can be gained about the effect of the disturbance on wildlife. No funding for personnel and other resources to simulate recreational disturbance is needed because these management experiments make use of actual recreational activities. Realism of the disturbances is ensured because actual recreationists and their activities are involved. With cooperation among natural resource agencies, management experiments can be devised to address recreational disturbances that span spatial and temporal scales.

Management experiments are not often used to assess recreational disturbance on wildlife, but they should be used whenever feasible (Gutzwiller 1993). A single experiment may not reveal the specific facet or level of recreational disturbance that underlies a problem, so researchers should be prepared to conduct a series of experiments. Initial management experiments should consider broad ranges of one or more suspected disturbance factors (e.g., location, duration, frequency, intensity, spatial scale, or seasonal timing), and follow-up experiments should focus increasingly on recreation aspects that previous experiments in the series indicated were most influential (Gutzwiller 1993). User groups may object to manipulation or curtailment of their activities during such experiments, but wildlife scientists should explain that these experiments are in the best long-term interests of wildlife and recreationists. These experiments are the best way to

identify the actual cause of a problem; this knowledge may prevent unnecessary closure of areas to recreationists, or it may preclude the need to even regulate a recreational activity.

### Non-experimental Studies

When constraints on logistics, funding, time, or other resources preclude experimental assessment, non-experimental studies can often be used to identify associations between recreational disturbance and wildlife responses. Compared to experimental studies, non-experimental studies may be more realistic to implement because they can be quicker, easier, and less expensive to conduct (Gutzwiller 1991). These characteristics may be especially advantageous when influence of a recreational activity must be discerned quickly, as might be the case when species of special concern are involved. A non-experimental study also can be valuable as a way to gain general insight about recreational impacts because such a study can be broader and more holistic than can most field experiments. Wildlife scientists can use non-experimental studies to help identify the most relevant factors and hypotheses to address in subsequent experiments.

Through measurement of wildlife responses for disturbed and undisturbed study units, both before and after recreational activity, the study design of non-experimental studies can be used to avoid many biases. Control of the effects of extraneous variables on inferences also can be accomplished analytically with such techniques as regression or analysis of covariance (Huitema 1980). Non-experimental studies are based not on experimental manipulation of a recreational activity but on observed associations. These studies are therefore subject to spurious interpretations that can originate from confounded effects. For example, it would be difficult to separate the effects of recreational disturbance and food availability on habitat use by a species if the recreational activity coincided (was confounded) in space or time with weather-induced changes in food density. Thus, other factors being equal, inferences about cause-and-effect relations cannot be made with as much confidence from non-experimental studies as they can from experimental studies.

### Complex Effects

Although complex influences—including interaction, cumulative, ripple, threshold, and lag effects—may often reflect reality better than do simple main effects, wildlife scientists have not typically assessed complex effects of recreational disturbance on wildlife. Main effects occur when levels of an independent variable differ in their influence on a response variable; interaction effects occur when the effect of one independent variable changes with the levels of another independent variable (Fig. 2). Wildlife scientists should consider whether there are interaction effects between different aspects of the same recreational activity (e.g., number of visitors and seasonal timing for wildlife viewing) or between different types of recreation (e.g., hiking and angling). Interaction effects of recreational activities and environmental conditions (e.g., habitat quality, food availability) also should be considered because impacts of recreationists may vary with ecological states and natural disturbances. Two-way interaction effects on a wildlife response variable are the simplest to study (Box 1).

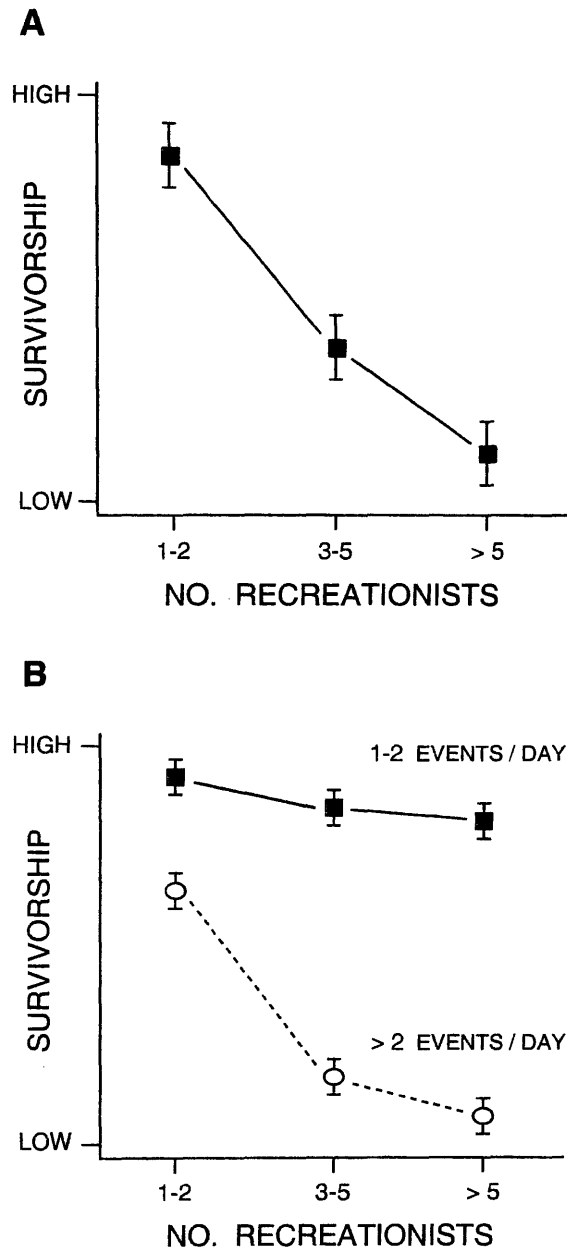


Fig. 2. Illustration of a main effect (A), in which a wildlife response variable (e.g., mean survivorship  $\pm 2$  SD) differs among levels of one independent variable (e.g., number of recreationists); and an interaction effect (B), in which the influence of one independent variable (number of recreationists) on the response variable differs between levels of another independent variable (e.g., frequency of recreational activity).

Cumulative effects occur when impacts add up through time or space (Riffell et al. 1996). For a given type of recreation, a single disturbance may not generate a serious problem for wildlife, but recurring disturbances may lead to substantial problems through temporal or spatial summation of impacts. Consequently, some activities that have no obvious individual effects may result in cumulative impacts. It also is possible that recreational disturbances that have significant short-term or local effects may not result in temporally or spatially cumulative effects. The reason these outcomes are possible is that development of cumulative effects is affected in part by whether wildlife

**Box 1. Assessing interaction effects.**

Two-way interaction effects are usually easier to assess than are 3-way or higher-order interaction effects because they are easier to gather data for and interpret. To study 2-way interaction effects, one collects data on the dependent variable (wildlife response variable) for all combinations of the levels of 2 independent variables (also known as factors). Here we focus on the interaction effect of a recreational activity and an environmental condition.

Suppose that a biologist wants to know whether the number of fledglings for a species is influenced by an interaction involving the number of wildlife viewers and food abundance. For each nest (unit of analysis), the biologist would collect data on number of fledglings (dependent variable) for nests that were in areas with different numbers of viewers and different levels of food abundance. For breeding birds, one might estimate food levels by measuring arthropod abundance. The matrix below illustrates the basic design needed to assess 2-way interaction effects.

| Arthropod abundance (g/m <sup>3</sup> ) | Number of wildlife viewers/day |                  |                  |
|-----------------------------------------|--------------------------------|------------------|------------------|
|                                         | 0-2                            | 3-5              | 6-8              |
| 0-30                                    | 3, 3, 3, 4 (3.3)               | 2, 2, 1, 2 (1.8) | 0, 0, 1, 0 (0.3) |
| 31-60                                   | 2, 4, 4, 5 (3.8)               | 4, 3, 2, 4 (3.3) | 2, 2, 2, 3 (2.3) |
| 61-90                                   | 4, 3, 5, 4 (4.0)               | 3, 3, 5, 5 (4.0) | 3, 3, 4, 4 (3.5) |

We have 3 levels of each of the 2 factors, and we have number of fledglings for 4 nests (mean number of fledglings in parentheses) for each of the 9 factor-level combinations ( $n = 36$ ). It is reasonable to study from 2 to approximately 4 levels of each factor, but higher numbers of levels make it difficult to obtain adequate replication for each factor-level combination. The number of replicates shown here is for illustrative purposes only. Analysis of required sample sizes (see other chapters in this volume) should be used to calculate the number of replicates needed for each factor-level combination. Analysis of variance can be used to assess whether the effect of number of wildlife viewers on number of fledglings is statistically influenced by arthropod abundance.

Wildlife viewers may disturb adults and reduce the number of feeding visits to the nest. Number of feeding visits to the nest, and hence number of fledglings, also may be influenced by food abundance. In this example, mean number of fledglings generally decreases with increasing number of viewers, and the decreases are more severe (rates of decline are higher) with decreasing levels of arthropod abundance. Because the effect of number of wildlife viewers on number of fledglings differs between levels of arthropod abundance, we conclude the 2 factors interact to affect number of fledglings. A biological interpretation of this interaction effect is that the impact of wildlife viewers on number of fledglings gets progressively larger as food becomes less plentiful.

recovers from a disturbance before the next disturbance in time or space is encountered. If recovery to an undisturbed state occurs before wildlife experiences the next disturbance, cumulative effects are less likely to develop than if wildlife does not recover before the onset of the next disturbance (see Sousa 1984, Rapport et al. 1985, Petraitis et al. 1989, Spaling and Smit 1993, Riffell et al. 1996). Cumulative effects do not develop when the initial disturbance causes the maximum amount of impact possible. The study by Riffell et al. (1996) demonstrates how to assess whether a repeated recreational activity has temporally cumulative impacts on bird communities.

Ripple effects occur when the wildlife response to a disturbance leads to changes at other levels of biological organization, at other trophic levels, or at other places. Two examples illustrate these effects. If off-road-vehicle activities displaced numerous individuals from a carnivore population, predation by that species would decrease in the disturbed area. With reduced predation, the richness and evenness of the carnivore's prey community may change. Thus, disturbance at a population level may cause changes at a community level, and disturbance to one component of food chain (predator) may affect other food-chain components (prey). When recreational disturbances have effects beyond their site of origin, the influence of the original disturbance has rippled through space. For example,

boating activity may displace foraging waterfowl from a lake and force them to feed at undisturbed but overcrowded wetlands. Waterfowl may experience lower food availability or higher risks for diseases at such locations. In this instance, an influence at one place (displacement from lake) had an effect elsewhere (increased overcrowding and associated problems). Holistic thinking is needed to assess ripple effects (Box 2).

Wildlife responses to disturbances may exhibit thresholds (Fig. 3) or lags (Fig. 4), which can complicate detection of recreational effects. For example, a recreational disturbance may have little or no effect until it reaches a critical level (threshold), and this level will not be detected if it lies outside of the range of the disturbance variable considered. Similarly, a recreational disturbance may not induce a problem until well after the initial disturbance, and assessments that measure wildlife responses only immediately after the disturbance will fail to detect such impacts. To avoid these problems, researchers should conduct studies that involve a wide range of conditions for the disturbance variable and continue to monitor wildlife responses for some time after recreational activities cease. Decisions about how wide the assessed range of a disturbance variable should be can be based on the range of recreational disturbance that is possible or probable in a given area. Decisions about how long assessments should last

### Box 2. Assessing ripple effects.

The design of studies to assess ripple effects should center on probable connections between different levels of biological organization (e.g., individuals, populations, communities, ecosystems), between trophic levels (e.g., carnivores, herbivores), and between events at different places. To identify possible ripple effects of recreational disturbance, biologists need to think holistically about the biology of the species involved, especially about such issues as behavior, food habits, habitat requirements, natural-history characteristics, home range and territory sizes, relationships with other organisms (e.g., competitive, predator-prey, mutualistic), and the spatial connectivity of the landscape. Knowledge about the effect on wildlife from the disturbance that is presumed to initiate the ripple effect, obtained from the literature or field studies, also is important to consider.

The fundamental question is whether a recreational effect at one level of biological organization, trophic level, or place has an effect on wildlife at, respectively, another level of biological organization, trophic level, or place. Once the biologist identifies possible ways in which recreational disturbance may cause ripple effects, standard field research approaches can be used to assess whether hypothesized or suspected impacts are real. The following hypothetical scenario illustrates these ideas.

A biologist suspected that off-road-vehicle (ORV) activity was affecting use of streams by northern river otters (*Lontra canadensis*). The situation was perplexing, however, because observations indicated abundance of otters was not affected by ORV noise or the presence of the off-road enthusiasts themselves. A closer examination of the situation revealed that uplands and floodplains damaged by ORV tires were depositing sediment into nearby streams during heavy rains and spring thaws. The biologist hypothesized there may be a connection between this sediment, density of fish and aquatic invertebrates in the stream (river otter prey), and abundance of otters in the streams. She decided to assess whether there was a ripple effect of the ORVs that affected stream use by otters through sediment impacts on their prey.

The biologist obtained estimates of otter, fish, and invertebrate numbers for both stream groups (adjacent ORV activity, no adjacent ORV activity) at paired sites (i.e., 2 sites per location). Each pair involved 2 streams that were in close proximity to one another and that occurred in comparable landscape contexts; however, at each location, one stream had nearby ORV activity and the other did not. The paired design helped to control for variation in otter, fish, and invertebrate numbers associated with among-location differences in bank slope, rainfall, snowmelt, stream temperature, and stream depth, which can affect soil erosion or fish and invertebrate numbers. This design reduced the chance these factors would be confounded with (inseparable from) or obscure (through added variance) the effects of the ORVs on otters.

She found that fish and invertebrate numbers were lower in streams that experienced sedimentation from nearby ORV activity than in streams without nearby ORV activity. Otter numbers exhibited the same pattern. The biologist concluded that her study supported the hypothesis that ORV activity had a ripple effect on otters that was transmitted through a food-chain connection.

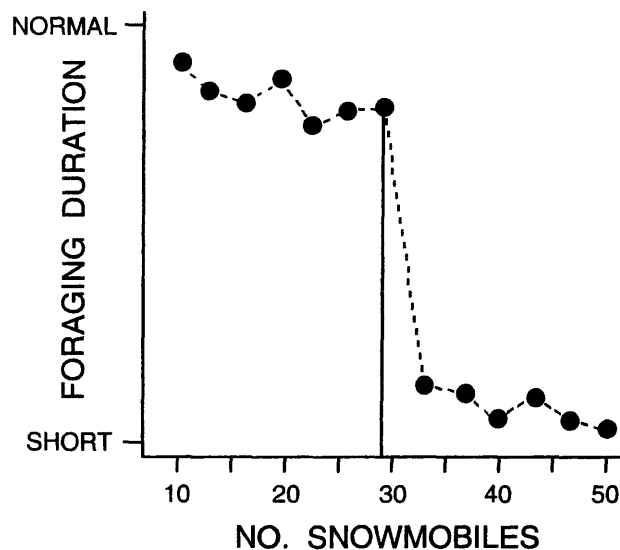


Fig. 3. Illustration of how to identify a recreational disturbance threshold. A plot of a wildlife response variable (e.g., foraging duration) versus a disturbance variable (e.g., number of snowmobiles) can be used to assess whether there is a disturbance level beyond which there is an abrupt change in the response variable—the threshold level of the recreational activity (vertical line).

following disturbances can be based on the length of time that the disturbance may appreciably affect the biology of the species (e.g., reproduction, survivorship) or the integrity of its habitat (e.g., availability of food and shelter).

Variables that represent complex effects are incorporated into studies in the design phase and assessed for their importance in the data-analysis phase. Complex effects cannot be revealed through an analysis of main effects alone. If complex effects were influential in a system, management based on information from a main-effects study would be misleading and may result in inappropriate management of wildlife or recreational activities. Thus, knowledge about complex effects is crucial for effective management, and assessments of disturbance should consider these effects.

### Deciding Which Response and Disturbance Variables to Measure

Management objectives, the potential for direct and indirect (habitat) effects, and the importance of addressing wildlife fitness (reproduction, survivorship, lifespan) should be used to decide which response and disturbance variables to measure. Variables that specifically address management objectives for wildlife and wildland recre-

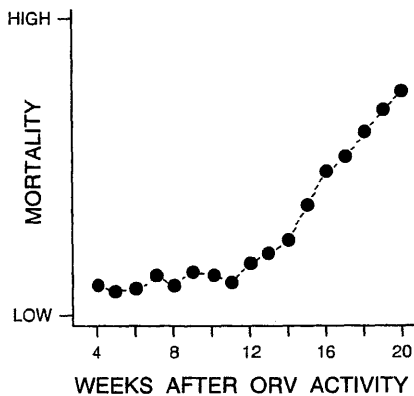


Fig. 4. Example of a lag in the effects of a recreational disturbance. If off-road-vehicle (ORV) activities during early fall damage winter-range vegetation such that winter forage quantity and quality are seriously reduced, effects of the disturbance may not become apparent until months later. Ungulate mortality is not influenced appreciably soon after ORV activities because most animals have not yet moved to winter range and energy demands are not yet high. But by mid or late winter, when high-quality forage is extremely limited and ungulates are struggling to maintain a positive energy balance, ORV damage to winter forage becomes apparent as animals succumb to reduced nutrition and harsh winter conditions.

ation must be studied, and the resulting data must be directly applicable to management situations. Managers should not have to extrapolate the results of a study to their particular situation. For example, if a management objective relates to wildlife reproduction, the response variable should be number of individuals produced, percent of young that survived to a certain date, or some other variable that directly reflects reproduction, not a variable that may only be a weak correlate, such as number of calling males. To be maximally useful, response and disturbance variables must directly reflect the spatial scale, time frame, and level of biological organization (e.g., population, community, ecosystem) that a management objective addresses (Box 3).

Studies that consider direct effects will require variables that measure actual wildlife responses at the level of individuals (e.g., behavior, physiology, productivity, and mortality), populations (abundance, distribution, and demographics), or communities (species composition and interactions) (Gabrielsen and Smith 1995, Knight and Cole 1995b). Studies of indirect effects will require variables that measure effects of recreational activity on soil, vege-

### Box 3. Measuring response and disturbance variables that directly address management objectives.

If biologists gather data about variables that are directly pertinent to a management objective, managers do not have to extrapolate or guess how to apply the study's results to their situation. This approach can help managers avoid inappropriate application of results and improve conservation effectiveness. The example that follows illustrates how one should match response and disturbance variables to the spatial scale, time frame, and level of biological organization that a management objective addresses.

Suppose the management objective is to regulate mountain biking activity (if necessary) so that reproductive activities of an elk (*Cervus elaphus*) population on the calving grounds are not impacted. Data for several response and disturbance variables are needed to assess whether there is need for concern about mountain biking and, if so, what aspect of this disturbance is problematic.

The spatial scale to be considered includes areas used by reproducing cows and their calves. The time frame includes the period just prior to, during, and immediately after calving. Outside of this time interval, mountain biking in the study area occurs either rarely or in areas not used by reproducing elk. If pregnant females were displaced from wintering areas and their nutritional status was compromised as a result, they may reproduce less successfully. But in the area for which the management objective was developed, this was not an issue because mountain biking did not occur on the wintering grounds. However, mountain bikers use areas that pregnant females use for feeding just prior to calving, so impacts on the health of cows at this time and in this part of their range are a concern. The population is the level of biological organization of interest here. Data for individual cows and their calves are needed to characterize reproductive activities for the population.

The biologist identifies several response variables that relate to reproductive performance so he can assess whether mountain biking disturbed reproductive activity. He considers measuring the percentage of time that cow elk spend in alert behavior or fleeing from mountain bikers, and whether females fitted with radio collars (including heart rate and movement sensors) are displaced from birthing areas or exhibit stress in the form of abnormal heart rates and daily movements. Because of limited time and resources, however, the biologist decides to focus on birth rate and calf mortality—fitness-related response variables. He also reasons that, compared to the behavioral and physiological variables he considered, these fitness variables would provide information that is more directly relevant to the population's reproductive performance.

Using the literature on elk responses to human activity during the breeding season, as well as his understanding of general ungulate behavior, the biologist identifies disturbance variables that have high potential for being problematic. He knows that important activities such as feeding and resting occur at specific times of day and decides to measure the daily timing of mountain biking activity throughout the identified time frame. For each day, the average size and number of mountain-biker groups also are estimated because the intensity of disturbance may be an issue. Ungulates may react more strongly to bikers that leave established trails (either on foot or with their bikes) than they may to bikers who remain on trails. Thus, the biologist decides to measure the daily frequency with which off-trail activity occurs and distances involved. If necessary, these disturbance variables can be manipulated by management, through restrictions on the daily timing of activity or number of mountain bikers, and through education about and enforcement of trail-use regulations.

tation, and water components of wildlife habitat. Examples of variables for assessment of indirect effects are soil compaction, erosion, rutting, productivity, chemistry, moisture, temperature, and microbiota; vegetation density, cover, species composition (including invasive exotic species), vertical structure, and spatial pattern; and water chemistry, turbidity, organic matter content, and flow (Cole and Landres 1995, Douglass et al. 1999). Response variables that measure wildlife fitness should be studied so that effects of recreation on processes that underlie long-term conservation (e.g., population dynamics, survivorship) can be better understood.

### Response Variables

Examples of response variables that relate directly to fitness include number of clutches or litters, clutch or litter size, average mass of young, percent survivorship of young and adults, recruitment into the breeding population, lifetime reproduction, mortality rate, and lifespan. Hatching efficiency, nest success, fledging efficiency, and potential replacement rate are additional fitness metrics that can be used to assess effects of recreational disturbance (Box 4).

Although fitness variables may be most important to consider, it is sometimes difficult to obtain adequate fitness data because of logistical constraints, limits to funding and other resources, inability to find reproduction sites, or the difficulty of capturing animals or studying individuals for extended periods. Variables that relate less directly to fitness can be valuable and are sometimes easier to measure. Examples of such variables include time spent brooding, foraging, being vigilant, and fleeing from recreationists; wildlife occurrence and abundance; and the distance from recreationists at which physiological, behavioral, reproductive, or distributional effects are induced (e.g., Burger 1991, Knight et al. 1991, Staine and Burger 1994, Klein et al. 1995).

### Disturbance Variables

Biologists should measure disturbance variables that can be directly regulated or manipulated through management actions. Examples of disturbance variables that may affect wildlife and that managers can alter include: mode of travel (e.g., vehicle, foot, stock, skis); type, frequency, predictability, spatial extent, location, daily and seasonal timing, duration, and speed of recreational activity; impacts to soil, vegetation, and water; noise properties and sources; and the total length or density of trails or roads that increase human access (e.g., Bowles 1995; Cole and Landres 1995; Knight and Cole 1995a,b; Claar et al. 1999; Gutzwiller and Anderson 1999).

Prior recreational activities should be considered in studies of present situations because the current status of wildlife at a site may reflect effects of previous recreational disturbances. For instance, large carnivores may have been displaced by previous disturbances, resulting in communities that now are depauperate in top predators despite an otherwise natural environment. Or a present lack of response to a recreational activity may reflect habituation to recurring disturbances that took place over several years, and the initial effects of disturbances on the individuals or populations involved are no longer apparent.

Historical data for disturbance variables can be used to assess impacts of prior activities on present conditions.

#### Box 4. Additional examples of fitness variables.

Gehlbach and Gehlbach (2000) reported results of studies that assessed whether recreationists impacted the reproductive success of whiskered screech-owls (*Megascops trichopsis*) in the Chiricahua and Huachuca mountains, Arizona during 1995–99. Most of the recreationists were birdwatchers (individuals and guided groups), but a few were campers and hikers. Recreationists visited whiskered screech-owl nests in camping areas and near trails, sometimes repeatedly. Disturbances included “Repeated use of tape recordings and imitations to call whiskered screech-owls into view, use of strong lights to see them at night, flash photography, and pounding or rubbing on nest trees to induce appearance...” (Gehlbach and Gehlbach 2000:18). The effect of the investigators’ research protocol on the owls was negligible.

Although first clutch hatching efficiency (hatchlings/eggs) was 84% for undisturbed clutches and 62% for disturbed clutches, the difference was not statistically significant. Undisturbed nests were 87% successful ( $\geq 1$  chick fledged), whereas disturbed nests were 70% successful, but these rates did not differ statistically. Undisturbed nests had an average of 2.8 nestlings and 2.7 fledglings, and these values were statistically higher than were those for disturbed nests (2.0 nestlings, 1.5 fledglings). Statistically significant differences also emerged for average fledging efficiency (fledglings/hatchlings) (87% for undisturbed, 65% for disturbed); productivity (fledglings/eggs) (84% for undisturbed, 57% for disturbed); and potential replacement rate (fledglings/breeding pair) (2.9 for undisturbed, 1.4 for disturbed).

For example, analyses could assess whether the present distribution of a rare species is correlated with seasonal timing, daily frequency, and spatial extent of ecotourist disturbance during previous years. Or one could examine whether the current abundance of a species that is popular with photographers is correlated with the amount of time that has elapsed since trails or roads were established. Present and historical data for disturbance variables also can be combined in a study to test for interaction effects of current and previous recreational disturbances (Box 5). Historical variables, which can provide insights about the long-term effects of recreational impacts, can be used to help develop management approaches and policies that foster the perpetual coexistence of wildlife and recreationists.

### MANAGING RECREATIONAL DISTURBANCE OF WILDLIFE

In terms of time, personnel, funding, disturbance to wildlife, and inconvenience to recreationists, it usually is less costly to preclude a recreational problem than it is to correct one. Although not all situations lend themselves to pre-emptive strategies, we recommend that managers

**Box 5. Assessing interaction effects of present and historical recreational disturbances.**

An interaction effect involving present and historical disturbances would imply the effect of present disturbance on wildlife depends on levels of the historical disturbance. Such an interaction would indicate a temporal connection between current and previous disturbances. Note that current and previous disturbances can be of the same type (e.g., present and historical boating activity) or of different types (e.g., present ecotourist numbers, historical backpacker use). A hypothetical example illustrates how one might assess these interaction effects.

A biologist is concerned that caving (recreational cave exploration) may affect the reproductive performance of bat populations. Because bats often breed in the same caves each year, and because caves in her study areas were visited by ecotourists during previous years, the biologist suspects the effect of current caving activity may be exacerbating impacts of prior ecotourist activity on bat reproductive performance. She decides to assess whether past ecotourist activity and current caving activity interact to affect present bat reproduction. The following matrix contains the data for the study.

| Previous<br>ecotourist activity (years) | Current caving activity (spelunker groups/week) |                         |                         |
|-----------------------------------------|-------------------------------------------------|-------------------------|-------------------------|
|                                         | 0                                               | 1-2                     | 3-4                     |
| 0                                       | 1.2, 0.9, 1.0, 0.8, 0.8                         | 1.0, 0.9, 0.8, 0.6, 0.7 | 0.8, 0.9, 0.6, 0.4, 0.5 |
| 1-3                                     | 1.1, 0.8, 1.0, 0.7, 0.9                         | 0.9, 0.7, 1.0, 0.7, 0.8 | 1.0, 0.9, 0.7, 0.3, 0.6 |
| 4-6                                     | 1.3, 0.7, 0.9, 0.8, 0.9                         | 1.2, 0.9, 0.8, 0.7, 0.5 | 0.9, 0.8, 0.5, 0.4, 0.7 |

Reliable data on the number of bat breeding seasons (years) during which ecotourists visited each of 45 caves were available for 6 prior consecutive years. Data for number of weeks during which spelunker groups visited each cave during the present breeding season were recorded. The mean number of young produced per female (table entries) was estimated for each of 5 caves for each of the 9 factor-level combinations. The biologist measured the size of areas within each cave that were suitable for bat breeding. This variable was used as a covariate in the analysis to control analytically for the effect of area of suitable breeding substrate on number of young produced per female. In the analysis, the covariate adjusts for differences among caves in breeding area so that interaction effects can be assessed without concern they are confounded with (indistinguishable from) effects of suitable breeding area.

The biologist used analysis of covariance to control for suitable breeding area and to test for an interaction effect of past ecotourism activity and current caving activity on present bat reproductive performance. She found there was no significant interaction effect, that previous ecotourism activity did not affect present reproduction, but that current caving activity decreased reproductive performance. The lack of an interaction effect indicated the effect of current caving activity did not depend on or vary with past ecotourist activity.

apply proactive (rather than reactive) approaches to manage recreational impacts whenever feasible.

### Framework for Management

Managing recreational disturbance of wildlife is both art and science. It involves value judgments as well as scientific information. Contemporary management frameworks attempt to bring values and science together (while making the distinctions clear) in processes that lead to effective management solutions to problems that are explicitly defined and based on societal values. The *Limits of Acceptable Change* process is the original and best known of these processes (Stankey et al. 1985). Another closely related process is *Visitor Impact Management* (Vaske et al. 1995). Managers need not use these processes as formal or rigid procedures. They are equally useful as informal ways to structure thinking and decision-making.

Each of these processes involves (1) identifying problems—situations where monitoring data (scientific information) show that management objectives (value judgments) are not being met, (2) implementing management solutions to problems based on insight into causal factors, and (3) obtaining feedback from periodic monitoring to assess both the effectiveness of management solutions and

whether new problems have developed (Fig. 5). Although these steps are conceptually simple, their implementation is often hindered by reluctance on the part of managers to make their value judgments as transparent and explicit as they are in this process. Implementation also is stymied by the challenge of making monitoring an integral, ongoing part of management. The alternatives—management in the absence of science or based on personal biases of mid-level managers—are no longer acceptable to a pluralistic and democratic society.

The initial steps in these frameworks involve collecting information, assessing values, and then codifying value judgments into quantifiable management objectives. Individual steps each result in a greater level of specificity for management objectives. The first step generally involves compiling legislative and policy mandates, earlier planning documents and planning constraints, and existing data. Some natural areas may have been established largely for protection of one or several species, whereas other areas may have been established to preserve natural landscapes and processes. Some areas may emphasize ecosystem preservation, whereas others might emphasize recreational opportunities. Particular attention should be given to describing the purpose of the area and its significance (or niche) at larger spatial scales. If the area is the primary

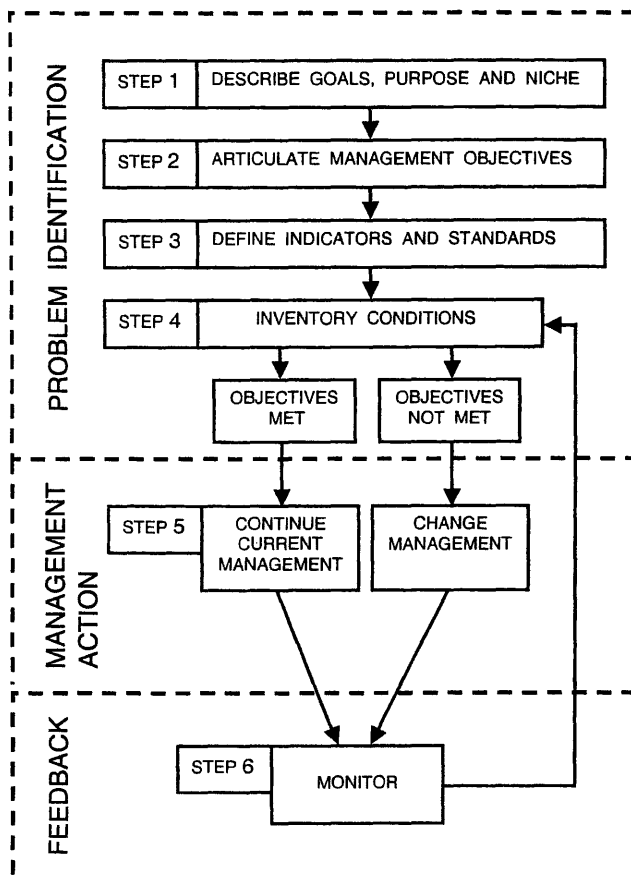


Fig. 5. A framework for managing recreational impacts on wildlife.

refuge for a particular wildlife species, management objectives are likely to be different than if the area is simply one of many refugia in the region. Broad statements of goals, purpose, and significance or niche are the products of this step.

The second step is to develop narrative descriptions of management objectives or what are frequently referred to as *desired future conditions*. This is a prescriptive step as it is a statement of what should be rather than a description of what is present. Generally, objectives address ecological, social, and managerial conditions. They describe appropriate compromises between competing objectives. For example, area goals might be to provide not only recreational access to beaches, but also to ensure the preservation of beach-nesting birds. Objectives might state there will be minimal disturbance of nesting birds, with recreational use allowed only to the extent that birds are not disturbed on nests. This compromise will result in different management and different conditions than will one in which recreational access is given a higher priority than is protection of birds.

This can be an uncomfortable step for many managers because it involves making value-laden decisions that have serious consequences. Decisions will promote certain life forms and landscapes and be detrimental to others. They will be favorable to some people and unfavorable to others. Particularly in large areas, several different zones may be established, each with unique objectives. This provides one means of favoring the needs of a broader diversity of

life forms and the desires of a wider spectrum of recreationists.

The third step, defining indicators and standards, amounts to stating objectives in quantifiable terms. Indicators are measurable variables that are either important components of desired conditions or that are related to (or proxies for) those conditions. For example, given the objective of minimal disturbance of nesting birds, an indicator might be number of abandoned nests, and a proxy indicator might be the number of vehicles/day observed within the nesting area. Standards are the limits—generally the minimum acceptable conditions—assigned to each indicator. In our nesting bird example, the standard might be no more than 2% of nests abandoned, or no more than one vehicle/day. If there are multiple zones, each zone may have the same indicator but a different standard.

The fourth step involves inventorying conditions, with most attention given to monitoring selected indicators. In this way, existing conditions can be compared to standards. By definition, where conditions are out of compliance with standards, a problem exists that requires management attention. Through this process, problems have been identified in a more objective and comprehensive manner than has been the norm. Problem definition, in theory, flows from agreed-upon value judgments (objectives and standards) and scientific data (inventoried conditions).

The fifth step is to develop or fine-tune management programs to reflect where problems do and do not occur. Where conditions are in compliance with standards, little change in management is needed. However, where they are not in compliance, managers need to search for causes of problems and implement management actions with the potential to alleviate problems.

The final, often-neglected step in the process is monitoring. Periodically, conditions need to be monitored both within an adaptive management framework (to assess the effectiveness of management programs and how they might be fine-tuned), as well as to reassess whether management objectives are being met. Too often, planners, managers, and researchers perceive monitoring as something that should be someone else's responsibility. Also, monitoring is frequently perceived as an end rather than a means, and as a task rather than a tool. Monitoring is a tool for (1) developing the understanding needed to build an effective management program, and (2) obtaining the scientific evidence for defending your management program if necessary.

### Management Strategies

There are many potentially effective approaches for managing recreational disturbance of wildlife. Working through a management framework should narrow the array of alternatives by (1) specifying problems in terms of what, where, and when, and (2) suggesting the relative social acceptability of different approaches. However, it is important to consider all possible management avenues, and it is often most effective to combine approaches and attack a problem from several different perspectives. It is particularly helpful to consider the strategic purpose of alternative management actions.

Fundamentally, the magnitude of wildlife disturbance is a function of the magnitude of recreational disturbance and the vulnerability of wildlife to that disturbance. This sug-

**Table 1.** Strategies for managing recreational impacts on wildlife.

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|                                        |                                               |
|----------------------------------------|-----------------------------------------------|
| Manage People                          |                                               |
| • Reduce amount of recreational use.   |                                               |
| • Reduce per capita impact of use.     |                                               |
|                                        | Manipulate type of use.                       |
|                                        | Manipulate visitor behavior.                  |
|                                        | Concentrate recreational use.                 |
|                                        | Manipulate location of use.                   |
|                                        | Manipulate timing of use.                     |
| Manage Wildlife                        |                                               |
| • Reduce vulnerability to disturbance. |                                               |
|                                        | Increase habituation to recreational use.     |
|                                        | Decrease attraction to humans.                |
|                                        | Increase avoidance behavior.                  |
| Manage Wildlife Habitat                |                                               |
| • Reduce vulnerability to disturbance. |                                               |
|                                        | Attract wildlife to locations far from users. |
|                                        | Screen wildlife from recreationists.          |
| • Compensate for disturbance.          |                                               |
|                                        | Create new habitat.                           |
|                                        | Improve habitat quality.                      |

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gests 3 basic strategies for management: (1) manipulate visitor characteristics to reduce recreational disturbance, (2) manipulate wildlife to reduce vulnerability to disturbance, and (3) manipulate habitat either to reduce wildlife vulnerability or to compensate for recreational disturbance. Each of these 3 primary strategies consists of several substrategies (Table 1).

#### *Manipulation of Visitor Characteristics*

Amount of recreational use is one obvious factor that influences the magnitude of disturbance. Some have suggested that carrying capacities for people should be developed, much as they have been for wildlife. Consequently, one strategy is to reduce or limit amount of use. There are many ways to limit use, ranging from requiring entry permits to more subtle approaches such as limiting parking spaces, making access more difficult, and even manipulating the type of information provided to visitors. Somewhat counterintuitively, reducing amount of use by itself is often not an effective management approach. The relationship between amount of use and amount of impact is often highly curvilinear. As use levels increase, additional use has less and less additional effect (e.g., Ferguson and Keith 1982). Consequently, use limitation may be most worthwhile in places where use levels are currently low and regulations are effective in keeping disturbance levels below thresholds (Hammitt and Cole 1998:256–257).

Other strategies try to reduce the per capita impact of recreationists (Table 1). The type of recreational activity can have a large effect on disturbance. Consider the difference in impact between a hunter and a photographer, or the difference in the extent of the area potentially impacted in a sand-dune ecosystem by a pedestrian versus someone driving an off-road vehicle. Although there are exceptions, motorized uses will generally cause more disturbance than nonmotorized uses, groups with stock and/or dogs will cause more impact than groups without animals, and overnight users cause more disturbance than day users

(Knight and Cole 1995b, Hammitt and Cole 1998: 182–198).

The behavior of recreationists may have an even greater influence on the magnitude of disturbance than type of activity. Disturbance depends on decisions about whether or not to approach wildlife and, if they are approached, how close to get to them. Studies have shown that fast-moving snowmobiles cause more disturbance of white-tailed deer (*Odocoileus virginianus*) than do slow-moving snowmobiles, but the greatest disturbance occurs when the snowmobile stops (Richens and Lavigne 1978). Noisy behavior also can be particularly problematic (Bowles 1995). Although some of the worst cases of disturbance are caused by malicious acts, well-intentioned but uninformed people likely cause most impact.

The spatial distribution of use affects both the overall amount and distribution of impact. In most situations, impact on wildlife should be less when use is concentrated as opposed to widely dispersed. Indirect impacts on wildlife from destruction of habitat are least when use is concentrated, as are direct impacts such as feeding or harassment. Concentration also increases the predictability of human activity. Many animals habituate to (and therefore are not highly disturbed by) human activities that are predictable and nonthreatening (Knight and Cole 1995a). Miller et al. (2001) found, for example, that the alert distance, flush distance, and distance moved by deer and birds increased when hikers were off-trail compared to when hikers were on-trail. They attributed these results to trail-use habituation by wildlife and to the unpredictability of off-trail activity.

The location where recreation occurs also influences the magnitude of disturbance. When recreational activities occur near or even within the view of nest sites, nests can be abandoned or more frequently subject to predation (Miller et al. 1998). However, Miller and Hobbs (2000) showed that relationships are far from simplistic. They found that birds that were able to nest close to trails actually suffered less nest predation, presumably because predators avoided trails. Activities close to preferred feeding sites can result in reduced feeding, increased energy expenditure, and even displacement of birds to less-productive habitat (e.g., Stalmaster and Kaiser 1998).

Finally, timing of recreational use has a pronounced effect on the likelihood of serious impact because animals are most susceptible to disturbance at certain critical times of the year, most notably during the nesting season for birds and the post-natal period for mammals. This may be an oversimplification, however. There is substantial evidence that disturbance while feeding can be cause for concern as well (Hobbs 1989, Skagen et al. 1991). Moreover, some species are particularly vulnerable at certain times because they become highly concentrated. Examples include migrating birds concentrated on stopover sites, and amphibians that are migrating during the breeding season.

#### *Manipulation of Wildlife*

There may be some potential to manipulate wildlife so they are not severely impacted by ongoing recreational disturbance. The most obvious examples are aversive conditioning of animals that are attracted to humans, and attempting to habituate animals to recreational activities. For example, black bears that have learned to associate

backpackers with food may destroy equipment and endanger human lives. Ultimately, bears that are attracted to human food are likely to be destroyed. In Glacier National Park, managers have used cracker shells, rubber bullets, and specially trained Karelian dogs in attempts to teach bears to stay away from human food (Joslin and Youmans 1999). It is not clear how successful such attempts have been. Bears also have been the subjects of successful attempts to habituate animals to human activities. In Alaska there are places such as McNeil River Falls where people come to watch brown bears fish in salmon streams. The bears' feeding habits are not disrupted by this activity because viewer number, location, timing, and behavior remain constant, and the bears habituate to the viewers (Aumiller and Matt 1994). Whittaker and Knight (1998) observe, however, that there can be unintended consequences of such efforts. Habituated bears, for example, may become easier targets for hunters and poachers outside of protected areas.

Manipulation of wildlife behavior may be particularly important for captive-raised animals. For example, one of the barriers to success of programs to re-establish the California condor (*Gymnogyps californianus*) in the wild is the reduction in avoidance behavior exhibited by released condors. As a result, condors spend more time in developed environments where they are more subject to a host of problems (e.g., flying into power lines) than they are when they remain in remote wildlands.

#### Manipulation of Habitat

Habitat modification can serve both to reduce disturbance and to compensate for recreational disturbance. Hockin et al. (1992) provide examples of manipulations that reduce disturbance, such as creating attractive nesting sites away from areas of recreational activity or visually screening recreationists from nesting sites. They also discuss examples of compensation, such as creating new habitat to replace habitat altered by recreational use (e.g., in wetlands) and improving the productivity or nutritional quality of feeding areas to which recreation displaces wildlife.

Burger (1995) reports on the positive effect of creating sandy shoals and inlet islands for colonially nesting birds in New Jersey. Signs had to be posted to keep boaters from using the islands for picnicking. However, even posting just half of an island as closed, with the other half available for recreation, increased breeding success. Habitat manipulations, such as feeding or fertilization of grass to attract wildlife to places where they come in contact with frequent, predictable, and nonthreatening activities, can increase wildlife habituation, reducing their vulnerability to disturbance.

#### Synergistic Effects

It is important to consider the effects of multiple management strategies working in combination. Limiting amount of use, by itself, is seldom an effective management strategy. However, it can be a highly effective supplement to actions that concentrate and control location of use. The most effective management programs generally apply a variety of management techniques, particularly visitor education, activity restrictions and zoning, and thoughtful design of roads, trails, and facilities.

### Visitor Education

Education is one of the keys to reducing recreational impacts on wildlife. The public needs to be informed about the values of wildlife, wildlife behavior, and the need to respect wild animals, as well as practical techniques for minimizing disturbance. By changing human behavior (Klein 1993), education can be an effective means of reducing per capita impact. Without education, impact management will be primarily reactive. Through education, management can become more proactive and preventive in nature. But there are limits to what education can accomplish. Education is not a panacea; instead, it is a foundation on which to build a comprehensive management program. Development of an effective low-impact educational program requires considerable thought. It requires attention to both content of educational messages and communication media that will be used to disseminate messages.

#### Message Content

Knowledge about appropriate low-impact techniques has developed slowly during the past few decades with accumulation of personal experience and recreation ecology research. But low-impact techniques related to wildlife continue to be poorly developed, in part because of site-specific, species-specific, and even individual-specific characteristics of wildlife disturbance. Progress in developing consistent educational messages for wildland users, in general, has been profound. Over the past 2 decades, numerous books have been written about low-impact use of wildlands (e.g., Hampton and Cole 1995), and a national *Leave No Trace* low-impact education program was developed (Swain 1996). *Leave No Trace* is a partnership between federal land-managing agencies, nonprofit educational organizations, and the recreation industry, with a mission to develop a nationally recognized minimum-impact education system to educate federal land managers and the general public through training, publications, videos, and electronic webs ([www.LNT.org](http://www.LNT.org)). With the *Leave No Trace* program, consistency in low-impact education has emerged, even among different land-managing agencies. This consistency is most apparent in the 7 low-impact principles that are the crux of the program (Table 2).

Although "Respect Wildlife" is 1 of 7 *Leave No Trace* principles, recommended behaviors are poorly developed. General recommendations include: (1) travel quietly and give animals the space they need to feel secure; (2) avoid approaching animals too closely, feeding them, or touching them; (3) learn about locations and times of the year when disturbance of animals is particularly problematic; and (4) leave pets at home or keep them under control. Individual managers must craft recommendations that are specific to

**Table 2.** Leave no trace principles.

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- Plan ahead and prepare.
  - Travel and camp on durable surfaces.
  - Dispose of waste properly.
  - Leave what you find.
  - Minimize campfire impacts.
  - Respect wildlife.
  - Be considerate of other visitors.
-

the situation that exists in the place they manage. The Leave No Trace program recognizes that education needs to be tailored to individual places and user groups. Behavior that may be appropriate in one place may be disastrous in another. Ultimately, visitors must accumulate the knowledge and wisdom to consider the many variables that delineate the most appropriate behavior for any given situation. Then they must use their own judgment.

### *Effective Communication*

There are many different ways to try to persuade recreation visitors to adopt recommended low-impact practices. Some of the most common educational media include brochures, personnel at agency offices, maps and signs, personnel in the field, and displays at visitor centers or in parking areas. Research by social psychologists, who have been studying persuasive communication for years (e.g., Eagly and Chaiken 1993), suggests that low-impact education is a difficult task. Informing people is relatively easy; gaining their commitment to change their behaviors is more difficult. Principles of low-impact education that have been compiled from experience and research are varied (Table 3) (Roggenbuck 1992).

### **Activity Restrictions and Zoning**

A common means of limiting disturbance is to restrict or prohibit activities that are particularly disturbing. Motorized use is perhaps the most common activity that is restricted, both because motorized use can be particularly destructive and motor vehicles can reach and disturb remote places. In some situations, however, motorized use is less disturbing to wildlife than is slow-moving, less-predictable pedestrian use (e.g., MacArthur et al. 1982). Activity restrictions commonly placed on hunters include limits on the number of shells they can carry and the type of shot they can use (Purdy et al. 1987). Anglers often must use certain types of bait and release the fish they catch. Off-trail travel and overnight camping might be prohibited or only permitted in designated sites.

Zoning is a means of restricting activities while not prohibiting them entirely. It involves dividing a large area into a number of different zones that vary in terms of what

recreational activities are allowed. Certain activities are allowed in some zones but not in others. In the context of managing wildlife, the general idea is to provide refuge for wildlife from repetitive disturbance. Depending on the situation, zones that provide refuge might be particularly critical locations for birthing, watering, roosting, or feeding, or they might simply provide some portion of the area to which disturbed animals can escape.

Zones might provide absolute protection from disturbance by prohibiting all recreational use. Alternatively, zones may only provide protection from severe types of disturbance. In these zones, recreational use would be allowed, but it might be restricted in quantity or in terms of the activities and behaviors that are allowed. In some zones, the only option for access might be to join a guided group of limited size. In other zones, recreationists might be required to travel on designated roads or trails. Some zones might only permit day use, whereas others may allow overnight use as well. Some zones might prohibit motorized use, hunting, or walking with dogs, while allowing other types of use.

Because timing can be critical to the overall effect of recreational disturbance, temporal restrictions can be an important component of a management scheme. Although temporal restrictions can be applied to entire areas, particularly if the areas are small, they are more commonly part of a zoning plan. Typically, use would be prohibited in critical locations (e.g., nesting sites) during crucial periods (e.g., nesting season). Knight and Temple (1995b) observed that, although most temporal restrictions involve seasonal closures for weeks or months, daily cycles of vulnerability also exist, with wildlife feeding mostly at night or primarily during the morning hours. In these cases, restrictions would be frequent but short-lived.

### **Wildlife-sensitive Design of Roads, Trails, and Facilities**

Wildlife disturbance is affected largely by where and when people and wildlife come in contact; thus, the design of traffic networks and facilities is critically important. Planning and design, to keep wildlife disturbance to acceptable levels, must be done at multiple spatial scales.

**Table 3.** Principles for effective communication.

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- Educational programs should be guided by specific objectives.  
It is important to identify specific problems and users that are the primary cause of the problems.
  - Focus the message.  
Address a few critical problems and desired behaviors instead of overwhelming the visitor with information. Clearly state the problem, type of behavior that aggravates the problem, and how a change in behavior will improve the situation.
  - Identify the audience.  
Different messages should be targeted to specific users and problems and delivered using different media in different places.  
For example, hunters should receive a different message than non-hunters and should be contacted in different places and manners (e.g., in hunter-safety classes). Certain behaviors and user groups will be more amenable to change than will others.
  - Use a combination of techniques.  
A combination of techniques allows messages to be repeated and makes it more likely that most visitors will be contacted.  
Personal contact supplemented with written materials can be particularly effective.
  - Present messages in a professional manner.  
Productions need not be slick, but they should not be perceived as amateurish. If they are, credibility will suffer. Text and dialogue should be accurate and easy to understand. High-quality equipment and materials should be used for graphics and productions. Personnel who contact the public should be cheerful, polite, outgoing, have a positive attitude, and be trained in communication skills and low-impact techniques.
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Particularly in smaller areas, linkages between the management area and surrounding lands must be considered. For example, it is important to consider the possibility of displacing wildlife from public to private lands, where increases in conflicts between humans and wildlife may occur. Impacts of noise and development, as well as the likelihood that nonindigenous species might invade from adjacent lands, should be considered. Regardless of the size of the management area, it is important to develop a broad-scale perspective of the distribution of species, their habitat, and their corridors of movement. Roads, facilities, and the flow of traffic should be designed to minimize vehicle collisions with wildlife, disruption of travel corridors, fragmentation of habitat, and impact to regionally rare species and habitats.

The location of access points or trailheads, beyond which motorized use is not allowed, can influence the spatial distribution of visitor use. If sensitive areas are far from the closest access point, use can often be kept to low levels without having to implement use limits or closures. Use distributions also can be influenced by the placement of facilities such as viewpoints, which attract use from sensitive areas.

Viewpoints can be located and designed to minimize impact. For example, cliff-nesting birds are less tolerant to disturbance when approached from the top of a cliff compared to when they are approached from the bottom (Herbert and Herbert 1965). Therefore, it would be better to place viewpoints at the cliff base. If overlooks are provided, they should be placed away from nest sites so that disturbance is limited (Hooper 1977). Larson (1995) describes a variety of design features built into a system of observation sites at a wildlife-viewing area in Colorado, where there was concern about disturbance of nesting great blue herons (*Ardea herodias*) and double-crested cormorants (*Phalacrocorax auritus*). Trails leading to the viewpoints were constructed such that colonies were approached tangentially instead of directly. In addition, timbers of varying height were placed vertically along trails to disrupt human profiles. Trails were built below ground level and existing vegetation was maintained to minimize visual intrusion.

Campgrounds also should be located and designed to minimize disturbance. Campgrounds are often placed in riparian zones because humans are attracted to water. However, the importance of riparian zones to wildlife means that location and design of riparian campgrounds are particularly critical. In a study of avian use of campgrounds, Blakesley and Reese (1988) found that species that nest on the ground or in shrubs and small trees were under-represented at campsites. To support a diversity of bird species in frequently disturbed places such as campgrounds, active intervention may be necessary to maintain a diverse vertical structure and appropriate spatial pattern of vegetation. Maintenance of shrub and tree patches between individual campsites and between the campground and stream banks is critically important for such species.

One of the keys to controlling wildlife disturbance is appropriate trail system design. Design at broad scales can leave substantial portions of the area without trails, providing refuges for wildlife. If possible, trails should avoid sensitive locations, such as ungulate wintering areas, key foraging areas, areas used for birthing and the immediate

post-natal period for mammals, and breeding areas for birds. At finer scales, trail design should seek to avoid fragmenting habitat and to provide adequate buffering between hikers and wildlife. It is often possible to use natural features (topography and vegetation) as visual and acoustic buffers.

Information about flush and flight distances can be helpful in deciding on desirable widths of buffer zones around refuges for wildlife. For example, in deciding where to locate their wildlife viewing facility in relation to nesting wading birds, Colorado Parks and Outdoor Recreation relied on the research of Erwin (1989) and others, which indicated that colonies of nesting wading birds did not respond to human intrusions at distances greater than 150 m (Larson 1995). Unfortunately, there can be considerable variation in flushing responses within the same species as well as over time (Knight and Temple 1995b). Fernández-Juricic et al. (2001) propose using alert distance (the distance between an animal and an approaching human at which the animal begins to exhibit alert behaviors to the human) as the most conservative estimate of minimum approach distance.

In addition to considering direct impacts on wildlife, trail system design should consider indirect impacts—impacts of recreation on vegetation, soil, and water, the living space and food source for wildlife. Like animals, vegetation and soil vary spatially and temporally in their vulnerability to disturbance (Hammitt and Cole 1998:155–173). Trails and facilities should be placed in more resistant environments. Careful trail design can reduce the need for spatial and temporal restrictions on use.

## SUMMARY

Recreational disturbance, which can detrimentally affect wildlife reproduction, survival, distributions, and behavior, is expected to increase in the coming decades. Wildland recreation occurs on most lands that are valuable for supporting wildlife, so the need to assess and manage recreational disturbances is pressing. To conserve wildlife and maintain support for wildlife from wildland recreationists, we advocate management actions that protect wildlife and permit recreational activity as long as it is not significantly harmful. Such approaches must be based on evaluations of existing data and, because recreational impacts are often context-dependent, new field studies. Study design and data analysis must consider not only simple main effects, but also complex influences of recreation (e.g., interaction, cumulative, ripple, threshold, and lag effects) that heretofore have largely been ignored. Field studies must involve wildlife response variables and recreational disturbance variables that are directly relevant to management objectives and that are responsive to management. A variety of techniques are available to manage recreational impacts. Most involve managing the behavior, activities, or distribution of recreationists, managing habitat, or designing facilities and transportation infrastructure that are minimally disruptive to wildlife.

## ACKNOWLEDGMENTS

We thank C. E. Braun, J. L. Marion, and S. K. Riffell for suggesting improvements to a draft of this chapter.

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