

M  
I  
L  
L  
E  
R  
+  
K  
N  
I  
G  
H  
T

**Influence of Recreational Trails on Breedi**  
OSMP Studies 4428

*Study*



Miller, Scott & Richard Knight

**Influence of Recreational Trails on  
Breeding Bird Communities**

**Miller, Scott & Richard Knight**

4428

Running Head: Recreational Trails and Bird Communities

INFLUENCE OF RECREATIONAL TRAILS ON  
BREEDING BIRD COMMUNITIES

Scott G. Miller

Richard L. Knight

Department of Fishery and Wildlife Biology

Colorado State University

Fort Collins, CO 80523

Clinton K. Miller

Department of Open Space

66 S. Cherryvale Road

Boulder, CO 80303

## ABSTRACT

As the number of individuals participating in outdoor recreational activities increases, the number of recreational trails crossing natural areas also increases. Because a primary goal of natural-lands managers is to ensure the coexistence of wildlife and humans, developing an understanding of how recreational activities effect wildlife becomes necessary. We investigated the influence of recreational trails on breeding bird communities in forest and mixed-grass prairie ecosystems in Boulder County, CO during 1994 and 1995. Species composition and rates of nest predation and Brown-headed Cowbird (Molothrus ater) were examined near and away from existing recreational trails and control transects. Species composition was altered due to the presence of trails in both ecosystems. Generalist species were more abundant near trails while some species were displaced away from trails. Within the grassland ecosystem, birds were less likely to nest near trails. Within both ecosystems, rate of nest predation was greater near trails. Within the forest ecosystem, rate of nest parasitism was not influenced by trails. No nest parasitism was found in the grassland ecosystem. Our results have important implications for the design and implementation of management policies regarding the coexistence of recreationists and wildlife.

*Key Words:* Colorado; recreation; recreational trails; bird communities; nest predation; nest parasitism.

*Key Phrases:* Recreational trails: effects on bird communities; Nest placement vs. distance from trails; Nest predation rates vs. distance from trails; Nest parasitism rates

vs. distance from trails; Displacement of birds away from trails; Attraction of birds to trails; Coexistence of recreationists and wildlife; Management of natural areas for recreation.

## INTRODUCTION

Outdoor recreational activities are increasing in popularity throughout the United States (Flather and Cordell 1995). Results from a national survey indicate that the number of individuals participating in nonconsumptive wildlife-oriented activities nearly doubled between 1980 and 1990 (U.S. Department of the Interior, Fish and Wildlife Service and U.S. Department of Commerce, Bureau of the Census 1993). Heretofore some have thought that nonconsumptive outdoor recreation was an environmentally benign activity. Increasing evidence, however, indicates that these activities can affect individual animals, populations, and wildlife communities (Knight and Gutzwiller 1995). Nonconsumptive outdoor recreationists affect wildlife primarily through unintentional (e.g., wildlife viewing, hiking) and secondarily through intentional (i.e., harassment) disturbance (Knight and Cole 1991). There is rising concern among scientists and natural-lands managers about the deleterious impacts that outdoor recreation may have on wildlife. For example, Boyle and Samson (1985) reported that in 81% of studies reviewed, nonconsumptive outdoor recreation had negative effects on wildlife.

Outdoor recreational activities such as hiking, jogging, and mountain biking require open space. Consequently, recreational use of open space land has risen steadily, and an increasing number of hiking and riding trails bisect natural areas, inevitably leading to increases in human/wildlife conflicts. Because trails bisect forest and grassland habitats, they may create habitat edges. Nest parasitism by Brown-headed Cowbirds (*Molothrus ater*) and nest predation typically increase in association with habitat edges (Whitcomb et al. 1981, Brittingham and Temple 1983), which may, in

turn, alter wildlife species diversity and composition (e.g., Ambuel and Temple 1983, Harris and Silva-Lopez 1992). Most habitat edge studies have been conducted in deciduous forests of the eastern United States with the majority investigating habitat edge effects of small isolated forest fragments surrounded by agricultural fields (see Paton 1994). Fewer studies have examined how landscape modifications resulting in the development of internal (e.g., roads, utility right-of-ways, recreational trails), rather than external (e.g., habitat islands) edges, affect bird communities.

Our knowledge of the influence of recreational trails on nest predation, nest parasitism, and wildlife community composition is rudimentary. Accordingly, our study investigated the influence of recreational trails on breeding bird communities in forest and grassland ecosystems along the Front Range of Colorado. Specifically, we addressed two null hypotheses: 1) species diversity, composition, and abundance did not differ along trails compared to away from trails, and 2) rates of nest predation and brown-headed cowbird parasitism did not differ along trails compared to away from trails.

## **STUDY AREA AND METHODS**

We conducted our study on City of Boulder Open Space and Mountain Parks properties, an area encompassing approximately 11,000 ha in and around the city of Boulder, Colorado (approximately 40° N latitude and 105° 18'45" E longitude). Part of this land is in agricultural production to preserve the historic culture of Boulder County; other parcels are set aside for outdoor recreation. Elevation within the study area

ranges from 1,219 to 2,438 m encompassing forest, riparian, shrubland, and grassland habitats. Visitor use on City of Boulder Open Space and Mountain Parks is almost 3 million visits per year with most visitors from the city of Boulder and surrounding communities. Visitor intensities are highest during the spring, followed by summer, fall, and winter seasons. Recreational activities include hiking, wildlife viewing, exercising pets, jogging, mountain biking, horseback riding, and rock climbing.

Study sites were located in pine forest and mixed-grass prairie ecosystems. Forest ecosystems were dominated by ponderosa pine (*Pinus ponderosa*) associated with a mix of shrubs, grasses, and forbs. Mixed-grass prairie ecosystems contained a variety of tall, mid, and shortgrass species including little bluestem (*Schizachyrium scoparium*), western wheat (*Agropyron smithii*), blue grama (*Bouteloua gracilis*), and side oats grama (*Bouteloua curtipendula*).

#### *Bird Communities*

We examined breeding bird communities along recreational trails and control transects. Control transects were staked lines established to measure bird communities where no trails existed. All trails and control transects were away from urban development and at least 400 m away from other trails and physiographic features such as forest edge, riparian areas, and ridge lines. Five trails and seven control transects were monitored in the grassland ecosystem. Twelve trails and seven control transects were monitored in the forest ecosystem. Mean trail width was 1.25 m (SE = 0.22) in the grassland ecosystem and 1.17 m (SE = 0.20) in the forest ecosystem.

Bird communities were surveyed using line transects (Buckland et al. 1993)

established parallel to trails at 0, 50, and 100 m away from trail centers. On control transects only the transect was surveyed. To examine the effects of trails (trail effect) on bird communities we compared control transects to 0 m trail transects. To examine the zone of influence of trails (distance effect) we compared bird communities along 0, 50 and 100 m transects. All transects were surveyed in a randomly assigned order once early (June) and late (July) in the breeding season during 1994 and 1995. Transects were surveyed from 1 hour before to 2 hours after sunrise and birds were recorded if detected within 25 m of the transect line. Total length of transects for each treatment were: 1) grassland trails, 0 m = 11,700 m, 50 m = 11,700 m, 100 m = 11,700 m; grassland control transects = 9,100 m, 2) forest trails, 0 m = 13,450 m, 50 m = 10,100 m, 100 m = 10,100 m; forest control transects = 8,400 m. Due to the juxtaposition of some trails in the forest ecosystem, an uneven number of transects were established at each distance away from trail centers.

#### *Nest success*

We located nests in the grasslands by dragging a heavy rope in 30 m wide swaths across the ground to flush birds from their nests during 23 May - 30 July, 1994 and 31 May - 21 July, 1995. Dragging was performed in a perpendicular direction to trails and control transects to maintain an equal sampling effort at all distances out to 200 meters. Once located, a nest was identified to species, marked with a small stake located 10 m north of the nest, and the perpendicular distance to the trail or control transect was recorded. Nests in the forest were located by following adults carrying nesting material or food items, observing behavior such as nest defense, and by

searching trees and branches during 2 June - 30 July, 1994 and 25 May - 31 July, 1995. Once located, a nest was identified to species, marked with a small piece of flagging tape on a nearby tree, and the perpendicular distance to the trail or control transect was recorded. All nests in grasslands and forests were monitored every three days until fledging of young or nest failure. Cowbird parasitism, including number of cowbird eggs or nestlings and fledging success, was noted.

### *Statistical Analyses*

Species diversity and evenness were evaluated using Simpson's Diversity Index (Begon et al. 1986). Due to small sample sizes we were not able to compute precise density estimates of individual species using standard methods (i.e., computer software program DISTANCE, Buckland et al. 1993). Therefore, we estimated an index of abundance (i.e., mean number of observations / 100 m of transect x 50 m width) of individual species at 0 m, 50 m, 100 m, and control transects. We used randomization tests (30,000 randomizations/test; Manly 1991, 1992) to compare abundance between transects. We compared abundance between 0 m transects and control transects to identify the effect of trail presence (trail effect) on bird communities. We compared abundance between 0, 50, and 100 m transects to identify the zone of influence of trails (distance effect) on bird communities. Data from each transect were pooled between early and late in the season. Because overall bird abundance did not differ between year (grassland  $P = 0.1419$ ; forest  $P = 0.3689$ ) data were pooled between year within the grassland and forest ecosystems, respectively, for analysis.

In the grassland ecosystem we maintained an equal search effort for nests at all

distances within 200 m of trails and control transects. Thus, we assumed that the distribution of nests in our sample represents the true distribution of all nests (detected and undetected). Logistic regression (GENMOD procedure, SAS Institute Inc. 1993) was used to determine if distance from trails or control transects was correlated with nest occurrence. Due to overdispersion of the data, a correction factor was included in the analysis, resulting in a test statistic based on the  $F$ -distribution. Because the nest searching techniques employed in the forest ecosystem were uneven we were not able to maintain an equal sampling effort at all distances away from trails and control transects, therefore forest nests were not used in this analysis.

Logistic regression was used to determine the relationship between nest predation and distance from trails and control transects for nests in grassland and forest ecosystems. Unless all nests in the analysis are observed from the day of nest initiation, serious biases could occur in estimation of survival rates (Mayfield 1975). Therefore, we analyzed nest predation data in a manner analogous to Mayfield's (1975) method, which provides unbiased estimates of survival rates (Bart and Robson 1982). Each individual day from the time a nest was located until the nesting attempt ended was considered an independent observation. When necessary, the end of a nest attempt was estimated as the midpoint between the last two visits. Four assumptions were made for this analysis (Johnson 1979, Bart and Robson 1982): (1) that nest outcome (either failure or success) was known, (2) that the date a nesting attempt ended was known, (3) that all nests had an equal probability of survival on each of the days, and (4) that each day was an independent observation, even though each nest

could contribute several days to the analysis.

Within both the grassland and forest ecosystems, year of study was not a significant predictor of nest predation (grassland, trails,  $\chi^2 = 0.170$ ,  $df = 1$ ,  $P = 0.6799$ , control transects,  $\chi^2 = 0.742$ ,  $df = 1$ ,  $P = 0.3995$ ; forest, trails,  $\chi^2 = 1.478$ ,  $df = 1$ ,  $P = 0.2241$ , control transects,  $\chi^2 = 0.004$ ,  $df = 1$ ,  $P = 0.9495$ ), therefore data were pooled between years.

Logistic regression was used to determine the relationship between brown-headed cowbird parasitism and distance from forest trails (no cowbird parasitism was found in the grasslands). For this analysis, each nest was considered an independent observation. Because Solitary Vireos (Vireo solitarius) were heavily parasitized (11 of 15 nests; 73%), two analyses were performed: 1) for Solitary Vireo nests alone, and 2) for all other species. Year was not a significant predictor of cowbird parasitism ( $\chi^2 = 0.974$ ,  $df = 1$ ,  $P = 0.1586$ ), therefore data were pooled between years.

## RESULTS

### *Bird communities*

Thirteen and 29 bird species were recorded in grassland and forest ecosystems, respectively. Species diversity and evenness differed little between 0 m, 50 m, 100 m, and control transects within either grassland or forest ecosystems (Table 1). Species diversity was approximately four times greater and species richness was about three times greater in the forest ecosystem as compared to the grassland ecosystem, whereas species evenness was similar.

We observed trail effects for a variety of species in both grassland and forest ecosystems. Three grassland species were significantly more abundant along control transects than along trails (Vesper Sparrow, Pooecetes gramineus,  $P = 0.0064$ ; Western Meadowlark, Sturnella neglecta,  $P = 0.0006$ ; Grasshopper Sparrow, Ammodramus savannarum,  $P = 0.0145$ ) (Figure 1). Six forest species were significantly more abundant along control transects than along trails (Western Wood-pewee, Contopus sordidulus,  $P = 0.0001$ ; Chipping Sparrow, Spizella passerina,  $P = 0.0001$ ; Pygmy Nuthatch, Sitta pygmaea,  $P = 0.0007$ ; Mountain Chickadee, Parus gambeli,  $P = 0.0388$ ; Townsend's Solitaire, Myadestes townsendi,  $P = 0.0139$ ; Solitary Vireo,  $P = 0.0023$ ). Conversely, in the forest, American Robins (Turdus migratorius) were significantly more abundant along trails than along control transects ( $P = 0.0028$ ) (Figure 1).

Along trails, we also detected distance effects. Two grassland species significantly increased in abundance with increasing distance from trails (Western Meadowlark,  $P = 0.0012$ ; Grasshopper Sparrow,  $P = 0.0407$ ) (Figure 1). The abundance of three forest species significantly increased with increasing distance from trails (Western Wood-pewee,  $P = 0.0002$ ; Chipping Sparrow,  $P = 0.0133$ ; Pygmy Nuthatch,  $P = 0.0268$ ). Conversely, American Robins were significantly more abundant near forest trails than away ( $P = 0.0447$ ) (Figure 1). Additionally, in the grasslands, Brewer's Blackbirds (Euphagus cyanocephalus) and Black-billed Magpies (Pica pica) showed a nonsignificant trend of increased abundance near trails. In the forest, although not statistically significant, House Finches (Carpodacus mexicanus) were

detected only along trails.

#### *Nest placement*

In the grassland ecosystem nests were significantly less likely to occur near trails than away from trails ( $F = 4.269$ ,  $P = 0.040$ ,  $n = 112$  nests). Along control transects, no trend was found, as nests were evenly distributed ( $F = 1.155$ ,  $P = 0.695$ ,  $n = 75$  nests) (Figure 2).

#### *Nest predation*

Within both the grassland and forest ecosystems we found a significant positive relationship between nest survival and distance from trails (grassland,  $\chi^2 = 8.615$ ,  $df = 1$ ,  $P = 0.0033$ ,  $n = 112$  nests,  $n = 1,954$  nest days; forest,  $\chi^2 = 3.886$ ,  $df = 1$ ,  $P = 0.0487$ ,  $n = 163$  nests,  $n = 2,040$  nest days). Nest survival did not vary with distance from control transects in either grasslands ( $\chi^2 = 0.3950$ ,  $df = 1$ ,  $P = 0.530$ ,  $n = 75$  nests,  $n = 965$  nest days) or forests ( $\chi^2 = 0.025$ ,  $df = 1$ ,  $P = 0.8754$ ,  $n = 92$  nests,  $n = 1,106$  nest days) (Figure 3).

#### *Nest parasitism*

No cowbird parasitism was found in the grassland ecosystem, either along trails or control transects. Within the forest ecosystem there were no relationships between cowbird parasitism and distance from trails for solitary vireo nests ( $\chi^2 = 0.122$ ,  $df = 1$ ,  $P = 0.7272$ ,  $n = 15$  nests) or for nests of all other species combined ( $\chi^2 = 1.110$ ,  $df = 1$ ,  $P = 0.2921$ ,  $n = 167$  nests).

## DISCUSSION

Because recreational trails interrupt the continuity of grasslands and forests, the creation of habitat edge is one mechanism by which trails may influence breeding bird communities. In general, effects of habitat edge are greatest on habitat-interior species, many of which show an avoidance of or occur at low densities near habitat edge (Kroodsmma 1984, Van Horn et al. 1995). Species which are adapted to habitat edge may be superior competitors, displacing habitat-interior species away from edges (Ambuel and Temple 1983). Additionally, rates of nest predation and nest parasitism are typically greater near habitat edge, further reducing habitat quality for nesting birds (see Paton 1994). Many nest predators are more numerous or concentrate predation activities near habitat edges (Gates and Gysel 1978, Whitcomb et al. 1981).

Another mechanism by which recreational trails may influence breeding bird communities is the associated human disturbance. Disturbance by recreationists can result in behavioral changes in birds such as species displacement as well as nest abandonment (Knight and Gutzwiller 1995). Species sensitive to disturbance by humans may show an avoidance or occur in reduced abundance in areas where human activity is common (Van der Zande and Vos 1994, Van der Zande et al. 1994).

Our results indicate that recreational trails can alter breeding bird communities in both grassland and forest ecosystems. Although species diversity, evenness, and richness differed little between 0 m, 50 m, 100 m, and control transects, species composition and abundance differed greatly. In particular, some species did not occur or occurred in lower densities near trails than at greater distances from trails, while

some species, mainly generalists, were more abundant near trails. For the majority of species found in reduced numbers near trails, the zone of influence of trails appears to be about 75 m, however, species such as Mountain Chickadee and Townsend's Solitaire appear even more sensitive to trails as they exhibited reduced numbers as great as 100 m away from trails.

A key question is whether recreational trails serve as habitat edge. Our results concur with Hickman's (1990) findings that trails can alter community composition. He found that habitat-edge species, such as Blue Jays (Cyanocitta cristata), American Robins, and Brown-headed Cowbirds were more abundant on sites with trails as compared to sites without trails. Furthermore, evidence suggests that fragmentation by other narrow open corridors, such as roads and utility right-of-ways, are sufficient to produce habitat-edge effects. For example, Ferris (1979), Kroodsmas (1982), Rich et al. (1994), and Hanowski and Niemi (1995) found that habitat-interior species were less abundant and habitat-edge species were more abundant near the corridors.

In addition to habitat edge effects, disturbance by recreationists may further alter species composition. For example, in The Netherlands, Van der Zande et al. (1994) showed that recreational disturbance had a depressing effect on densities in 8 of 13 avian species in adjacent groves and hedges. In another study, 11 of the 12 most common bird species showed a negative correlation between density and intensity of recreation in The Netherlands (Van der Zande and Vos 1984).

We found fewer nests near trails in the grassland ecosystem, further supporting that some species avoid habitats near trails. Gutzwiller et al. (1994) found that some

avian species exhibited a decrease in song occurrence and disruption of singing consistency caused by even low levels of human disturbance. Reijnen and Foppen (1994) presented evidence indicating that in areas where song was affected by disturbance, birds appeared reluctant to establish nesting territories. Because song is an integral component of breeding behavior (e.g., territory defense and mate attraction), it is reasonable to believe that birds sensitive to human disturbance may be reluctant to establish nest sites where human activity is frequent (i.e., near trails). Nest site selection is also influenced by rates of nest predation with a dispersion of nests away from areas of heavy predation pressure (Martin 1988). Therefore, fewer nests near trails may be, in part, a result of greater rates of nest predation in these areas.

Not only can trails affect the abundance and distribution of bird species, we found that nest predation was greater near trails. Paton (1994) reviewed studies investigating the influence of habitat edge on nest predation and found that 71% and 57% of the studies showed elevated levels of predation on artificial and natural nests, respectively, near habitat edges. Hickman (1990) and Rich et al. (1994) found that avian nest predators were attracted to recreational trails and transmission-line corridors, respectively. Both authors suggested that this attraction could result in greater rates of nest predation for birds nesting near these narrow open corridors.

Clearly, the predator assemblage in an area appears to be a key factor affecting rates of nest predation (Miller and Knight 1992). Although we were unable to evaluate the assemblage of potential mammalian nest predators, raccoons (*Procyon lotor*), skunks (*Mephitis sp.*), and coyotes (*Canis latrans*) were common on our study site

(pers. obs.). These species are often associated with habitat edges and humans (Gates and Gysel 1978). Avian nest predators such as corvids are also adapted to edge habitats and typically concentrate activities near habitat edges (Whitcomb et al. 1981, Wilcove 1985, Møller 1989). Our observations that Black-billed Magpies, a common nest predator, were more abundant near trails coupled with the possible attraction of mammalian nest predators may explain the greater rates of nest predation near trails.

Nest parasitism by Brown-headed Cowbirds is also considered an important element in reducing reproductive success of songbirds, especially near habitat edges (see Paton 1994). Cowbirds are considered common on the plains and foothills of Colorado (Sclater 1912, Bailey and Niedrach 1965, Davis 1969) and are typically associated with cattle (Rothstein et al. 1980). We, however, found no cowbird parasitism in the grasslands even though these sites were actively grazed during our study. Even more interesting, we did not detect cowbirds during grassland surveys, nor did we observe cowbirds during our nest searching and monitoring activities. We are unable to explain the absence of cowbirds on our grassland sites, however, others have found similarly unexpected results. For example, Hahn and Hatfield (1995) found significantly higher nest parasitism rates in forest-interior communities than on adjacent old field and edge communities even when traditional host species (i.e., old-field and edge species) were available. They suggested that cowbirds may switch habitats, either cyclically or opportunistically, to take advantage of non-traditional hosts (i.e., forest-interior species) which lack adequate defense strategies.

It has been suggested that cowbirds are attracted to and use open-corridors as access routes into forest interiors and, consequently, parasitize non-traditional (i.e., forest-interior) species (Small and Hunter 1988, Askins 1994). For example, cowbirds were attracted to nature trails (Hickman 1990) and open corridors as narrow as 2.5 m (Rich et al. 1994) in deciduous forests. We found no relationship between cowbird abundance or nest parasitism and distance from forest trails, suggesting that trails did not serve as access routes for cowbirds on our study area.

Because our study area was situated within an urban/suburban matrix, our results were no doubt influenced by the surrounding landscape (Engels and Sexton 1994). Furthermore, the intensity of recreational activities on our study area was extremely heavy. Therefore, caution should be used when extrapolating results obtained in our study to landscapes lacking either urban development, intense recreational pressure, or both. For example, Rocky Mountain National Park, located only 40 km from our study area receives similar recreational pressure, yet is almost an order of magnitude larger in size and is more removed from urban development. It is plausible that recreational trails in landscapes different than ours (e.g., Rocky Mountain National Park), may not exert similar effects on bird communities.

Our results indicate that trails may serve as habitat edges for some, but not necessarily all species. Additionally, the potential effect of recreational disturbance cannot be discounted. Thus, the question of whether the influence of recreational trails on bird communities is due to the physical presence of the trail, or rather the associated human disturbance remains, for the most part, unanswered. The possibility exists that

both mechanisms are acting in concert. Nonetheless, our results clearly show that trails can alter breeding bird communities in grassland and forest ecosystems, creating an arduous dilemma for natural-lands managers.

Because both wildlife and humans are components of natural areas, the goal of natural-lands managers should be to develop methods to ensure their coexistence (Knight and Gutzwiller 1995). However, until the effects of recreationists on wildlife communities are better understood, efforts to manage for this coexistence will be difficult. Management of natural areas must entail not only proper trail placement, but also recreationist management.

Natural-lands managers should participate in the design and placement of trails (e.g., proximity of trails to each other and sensitive wildlife habitat such as riparian areas, wetlands, and cliff lines). Consolidation of trails to certain areas (e.g., edges of forests and grasslands) will reduce the fragmentation of large interior blocks of habitat, maintaining less-disturbed areas for breeding birds.

Recreationists are more likely to support these and other types of restrictions if they understand how wildlife may benefit (Purdy et al. 1987). Thus, effective visitor education appears crucial to developing this understanding and ensuring proper trail etiquette. Instructional discussions with natural areas personnel can inform recreationists of how their activities affect wildlife and how they can modify their regime of disturbance (e.g., remaining on trails and keeping pets leashed) to minimize impacts. Klein (1993) found that visitors who spoke to wildlife refuge personnel were significantly less likely to disturb wildlife than recreationists who did not. By recognizing their impact

on natural areas recreationists can begin to develop a conservation ethic. Such an ethic can substantially minimize the increasing number of wildlife/human conflicts occurring on natural areas (Knight and Temple 1995).

The number of people participating in outdoor recreational activities is anticipated to increase in the future (Flather and Cordell 1995). As a result, the number of recreational trails crossing natural areas is also likely to increase. Until recently, the potential impacts of recreational trails and the associated human disturbance has been largely ignored. Our results indicate trails affect the distribution and abundance as well as the reproductive success of bird species, suggesting the need for more insightful trail planning and management of recreationists in natural areas.

## **ACKNOWLEDGMENTS**

We thank Don Dressler, Shawn McKinney, and Heather Johnson for assistance in the field. We are grateful to City of Boulder Open Space and City of Boulder Mountain Parks for their cooperation and financial support for this project.

## **LITERATURE CITED**

- Ambuel, B., and S. A. Temple. 1983. Area-dependent changes in the bird communities and vegetation of southern Wisconsin forests. *Ecology* **64**:1057-1068.
- Askins, R. A. 1994. Open corridors in a heavily forested landscape: impact on shrubland and forest-interior birds. *Wildlife Society Bulletin* **22**:339-347.

- Bailey, A. M., and R. J. Niedrach. 1965. Birds of Colorado. Denver Museum of Natural History, Denver.
- Bart, J., and D. S. Robson. 1982. Estimating survivorship when the subjects are visited periodically. *Ecology* **63**:1078-1090.
- Begon, M., J. L. Harper, C. R. Townsend. 1986. Ecology: individuals, populations, and communities. Sinauer Associates, Inc., Sunderland, Massachusetts. 876pp.
- Boyle, S. A., and F. B. Samson. 1985. Effects of nonconsumptive recreation on wildlife: a review. *Wildlife Society Bulletin* **13**:110-116.
- Brittingham, M. C., and S. A. Temple. 1983. Have cowbirds caused forest birds to decline? *BioScience* **33**:31-35.
- Buckland, S. T., D. R. Anderson, K. P. Burnham, and J. L. Laake. 1993. Distance sampling: estimating abundance of biological populations. Chapman & Hall, London.
- Davis, W. A. 1969. Birds in western Colorado. *Colorado Field Ornithologist*, Boulder, Colorado.
- Engels, T. M., and C. W. Sexton. 1994. Negative correlation of Blue Jays and Golden-cheeked Warblers near an urbanizing area. *Conservation Biology* **8**:286-290.
- Ferris, C. R. 1979. Effects of Interstate 95 on breeding birds in northern Maine. *Journal of Wildlife Management* **43**:421-427.

- Flather, C. H., and H. K. Cordell. 1995. Outdoor recreation: historical and anticipated trends. Pages 3-16 *in* Wildlife and recreationists: coexistence through research and management. R. L. Knight and K. J. Gutzwiller, eds. Island Press, Covelo, California.
- Gates, J. E., and L. W. Gysel. 1978. Avian nest dispersion and fledgling success in forest-field ecotones. *Ecology* **59**:871-883.
- Gutzwiller, K. J, R. T. Wiedenmann, K. L. Clements, and S. H. Anderson. 1994. Effects of human intrusion on song occurrence and singing consistency in subalpine birds. *Auk* **111**:28-37.
- Hahn, D. C, and J. S. Hatfield. 1995. Parasitism at the landscape scale: cowbirds prefer forests. *Conservation Biology* **9**:1415-1424.
- Hanowski, J. M., and G. J. Niemi. 1995. A comparison of on- and off-road bird counts: do you need to go off road to count birds accurately? *Journal of Field Ornithology* **66**:469-483.
- Harris, L. D., and G. Silva-Lopez. 1992. Forest fragmentation and the conservation of biological diversity. Pages 198-237 *in* Conservation biology: the theory and practice of nature conservation, preservation, and management. P. L. Fiedler and S. K. Jain, eds. Chapman and Hall, New York, New York.
- Hickman, S. 1990. Evidence of edge species attraction to nature trails within deciduous forest. *Natural Areas Journal* **10**:3-5.
- Johnson, D. H. 1979. Estimating nest success: the Mayfield method and an alternative. *Auk* **96**:651-661.

- Klein, M. L. 1993. Waterbird behavioral responses to human disturbances. *Wildlife Society Bulletin* **21**:31-39.
- Knight, R. L., and D. N. Cole. 1991. Effects of recreational activity on wildlife in wildlands. *Transactions of the 56<sup>th</sup> North American Wildlife and Natural Resources Conference* **56**:238-247.
- Knight, R. L., and K. J. Gutzwiller, eds. 1995. *Wildlife and recreationists: coexistence through research and management*. Island Press, Covelo, California. 384pp.
- Knight, R. L., and S. A. Temple. 1995. *Wildlife and recreationists: coexistence through management*. Pages 327-333 *in Wildlife and recreationists: coexistence through research and management*. R. L. Knight and K. J. Gutzwiller, eds. Island Press, Covelo, California.
- Kroodsma, R. L. 1982. Edge effect on breeding forest birds along a power-line corridor. *Journal of Applied Ecology* **19**:361-370.
- Kroodsma, R. L. 1984. *Effect of edge on breeding forest bird species*. *Wilson Bulletin* **96**:426-436.
- Manly, B. F. J. 1991. *Randomization and Monte Carlo methods in biology*. Chapman and Hall, New York, New York. 281pp.
- Manly, B. F. J. 1992. *RT: a program for randomization testing*. Version 1.02. West, Inc., Cheyenne, Wyoming. 17pp.
- Martin, T. E. 1988. Processes organizing open-nesting bird assemblages: competition or nest predation? *Evolutionary Ecology* **2**:37-50.

- Mayfield, H. F. 1975. Suggestions for calculating nest success. *Wilson Bulletin* **87**:456-466.
- Miller, C. K., and R. L. Knight. 1993. Does predator assemblage affect reproductive success in songbirds? *Condor* **95**:712-715.
- Møller, A. P. 1989. Nest site selection across field-woodland ecotones: the effect of nest predation. *Oikos* **56**:240-246.
- Paton, P. W. C. 1994. The effect of edge on avian nest success: how strong is the evidence? *Conservation Biology* **8**:17-26.
- Purdy, K. G., G. R. Goff, D. J. Decker, G. A. Pomerantzy, and N. A. Connelly. 1987. A guide to managing human activity on National Wildlife Refuges. Human Dimensions Resources Unit, Department of Natural Resources, Cornell Univ., Ithaca, New York.
- Reijnen, R., and R. Foppen. 1994. The effects of car traffic on breeding bird populations in woodland. I. Evidence of reduced habitat quality for willow warbler (*Pyloscopus trochilus*) breeding close to a highway. *Journal of Applied Ecology* **31**:85-94.
- Rich, A. C., D. S. Dobkin, and L. J. Niles. 1994. Defining forest fragmentation by corridor width: the influence of narrow forest-dividing corridors on forest-nesting birds in southern New Jersey. *Conservation Biology* **8**:1109-1121.
- Rothstein, S. I., J. Verner, and E. Stevens. 1980. Range expansion and diurnal changes in dispersion of the Brown-headed Cowbird in the Sierra Nevada. *Auk* **97**:253-267.

SAS Institute Inc. 1993. SAS® Technical Report p-243, SAS/STAT® Software: The GENMOD Procedure, Release 6.09, SAS Institute Inc., Cary, North Carolina. 88pp.

Sclater, W. L. 1912. A history of the birds of Colorado. Witherby & Co., London.

Small, M. F., and M. L. Hunter. 1988. Forest fragmentation and avian predation in forested landscapes. *Oecologia* 76:62-64.

United States Department of the Interior, Fish and Wildlife Service, and United States Department of Commerce, Bureau of the Census. 1993. 1991 National survey of fishing, hunting, and wildlife-associated recreation. Washington, D.C.; United States Government Printing Office.

Van Horn, M. A., R. M. Gentry, and J. Faaborg. 1995. Patterns of Ovenbird (*Seiurus aurocapillus*) pairing success in Missouri forest tracts. *Auk* 112:98-106.

Whitcomb, R. F., C. S. Robbins, J. F. Lynch, B. L. Whitcomb, M. K. Klimkiewicz, and D. Bystrak. 1981. Effects of forest fragmentation on avifauna of eastern deciduous forest. Pages 125-205 in *Forest dynamics in man-dominated landscapes*. R. L. Burgess and D. M. Sharp, eds. Springer-Verlag, New York.

Wilcove, D. S. 1985. Nest predation in forest tracts and the decline of migratory songbirds. *Ecology* 66:1211-1214.

Zande, A. N. van der and P. Vos. 1984. Impact of a semi-experimental increase in recreation intensity on the densities of birds in groves and hedges on a lake shore in the Netherlands. *Biological Conservation* 30:237-259.

Zande, A. N. van der, J. C. Berkhuisen, H. C. van Latesteijn, W. J. ter Keurs, and A. J. Poppelaars. 1984. Impact of outdoor recreation on the density of a number of breeding bird species in woods adjacent to urban residential areas. *Biological Conservation* **30**:1-39.

**Table 1.** Species diversity, evenness, and richness of bird communities along transects in grassland and forest ecosystems during 1994 and 1995, City of Boulder Open Space and Mountain Parks, Boulder, CO, USA.

<u>Grassland</u>			
	Species	Species	Species
Transect	Diversity	Evenness	Richness
0 Meter	2.251	0.375	6
50 Meter	2.825	0.283	10
100 Meter	2.616	0.327	8
Control	2.109	0.422	5
<u>Forest</u>			
	Species	Species	Species
Transect	Diversity	Evenness	Richness
0 Meter	8.039	0.423	19
50 Meter	8.533	0.449	19
100 Meter	8.570	0.357	24
Control	7.840	0.357	17

**Figure 1.** Index of abundance of birds detected along 0 m, 50 m, 100 m, and control transects in the grassland and forest ecosystem during 1994 and 1995, City of Boulder Open Space and Mountain Parks, Boulder, CO, USA.

**Figure 2.** Predicted probability a nest will occur at a given distance from trails and control transects within the grassland ecosystem during 1994 and 1995, City of Boulder Open Space and Mountain Parks, Boulder, CO, USA.

**Figure 3.** Predicted probability a nest will survive one day at a given distance from trails and control transects within the grassland and forest ecosystems during 1994 and 1995, City of Boulder Open Space and Mountain Parks, Boulder, CO, USA.

Mean ( $\pm$  SE) Number of Observations / 100 m of Transect (50 m width)





