EFFECTS OF TIMBER HARVESTING ON BIRDS IN THE BLACK HILLS OF SOUTH DAKOTA AND WYOMING, USA.

Brian L. Dykstra [1,2], Mark A. Rumble [3], and Lester D. Flake [1]

[1] Department of Wildlife and Fisheries Sciences, South Dakota State University, Brookings, SD 57007. PHONE 6056884781, FAX 605-688-4515

[2] Current address: U. S. Department of Agriculture, Forest Service, Apache-Sitgreaves National Forest, P.O. Box 968, Overgaard, AZ 85933-0968. PHONE 520-535-4481, FAX 520-535-5972

[3] U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, 501 East St. Joseph, Rapid City, SD 57701. PHONE 605-394-1960, FAX 605-394-6627

ABSTRACT

Timber harvest alters structural characteristics in ponderosa pine forests. In the Black Hills, harvested stands with 40-70% overstory canopy cover are managed as sapling/pole (3.0 - 22.9 cm dbh) or mature (> 22.9 cm dbh) stands. Changing the forest structure to two size classes has unknown effects on bird communities in this region. We counted birds in 20 harvested and 20 unharvested ponderosa pine stands during May and June of 1993 and 1994. Harvested stands represented the desired long-term conditions of stands managed for timber production. Forty-seven bird species were recorded; 29 species occurred in ≥5 stands and were included in statistical analyses. Abundances of nine species differed between harvested and unharvested stands. Red-breasted nuthatches (*Sitta canadensis*) (P = 0.03), ovenbirds (*Seiurus aurocapillus*) (P < 0.01), and black-headed grosbeaks (*Pheucticus meianocephalus*) (P = 0. I0), were more abundant in unharvested stands. Hairy woodpeckers (*Picoides villosus*) (P = 0.03), western wood-pewees (*Contopus sordidulus*) (P = 0.02), Townsend's solitaires (*Myadestes townsendi*) (P = 0.04), American robins (*Turdus migratorius*) (P < 0.01), chipping sparrows (*Spizella passerina*) (P < 0.0l), and dark-eyed juncos (*Junco hyemalis*) (P < 0.01) were more abundant in harvested stands. Species richness (P = 0.20) did not differ between treatments. Further stratification of stands into sapling/pole, harvested mature, unharvested mature, and old growth seral stages, brought forth more subtle differences in bird use of pine stands, most notably use of stands with larger trees by northern flickers (*Colaptes auratus*), use of sapling/pole harvested stands by black-backed woodpeckers (Picoides *arcticus*), and use of old growth stands by brown creepers (*Certhia americana*). Harvested stands had different breeding bird communities than those that were unharvested

Key words: Birds, Timber Harvest, Ponderosa Pine

INTRODUCTION

Timber harvest can disrupt structural continuity (Lord and Norton 1990, Ripple et al. 1991) and floristic patterns of the plant communities of forests (Franklin and Forman 1987). Altering vegetation profiles sometimes affects bird abundance and composition (Freemark and Merriam 1986, Szaro and Balda 1979). Forest bird communities are strongly influenced by vegetative structure (e.g., MacArthur and MacArthur 1961, James and Warner 1982) and floristic composition (Rotenberry 1985). Abundances of habitat generalists or species that prefer early seral habitats are likely to increase following timber harvest (Probst and Crow 1991). Birds preferring dense forest or late seral habitats often decline following timber harvest (Hejl et al. 1995).

The Black Hills National Forest consists of 486,000 hectares of predominately ponderosa pine forest. It is managed for many diverse and sometimes conflicting uses . including timber, wildlife, range, water, and recreation. Because of its size and location in the northern Great Plains, both eastern and western birds inhabit the Black Hills. Today, most of the forested land in the Black Hills is managed for timber production using shelterwood harvest methods. The National Forest Management Act of 1976 mandates the Forest Service to maintain the presence and viability of all species that occur within National Forest boundaries. Timber harvest in the Black Hills and other regions is often contested because of insufficient knowledge regarding the effects it has on wildlife.

We compared the breeding bird community in harvested ponderosa pine stands with that in unharvested stands. Harvested stands are managed toward a desired future condition of approximately 18 m^2 basal area/ha, which reflects stand conditions over the majority of the rotational age. Therefore, any effects noted can be projected to indicate the long-term consequences of timber harvest in the Black Hills.

STUDY AREA AND METHODS

The Black Hills of South Dakota and Wyoming are on the Missouri Plateau of the Great Plains in western South Dakota and eastern Wyoming. The Black Hills is an island of forest extending approximately 200 km north to south and 100 km east to west in the mixed grass prairie (Hoffman and Alexander 1987). Ponderosa pine comprises the majority of forests in the Black Hills, but quaking aspen, bur oak (tree and shrub form), and white spruce forest types also occur (Hoffman and Alexander 1987). Elevations range from 1065 m to 2207 m above mean sea level. Average daily temperatures extend from -8°C in January to 23°C in July, and annual precipitation. averages about 55 cm (Orr 1975). We conducted this study along the South Dakota/Wyoming state line (longitude 104º03'15" in the northern 1/4 of the Black Hills.

We selected 40 ponderosa pine stands, 20 which had received a light to moderate shelterwood cut during the past 10-I5 years (harvested stands) and 20 that had little or no timber harvest for >40 years (unharvested stands). Within each treatment, two seral stages were selected. Harvested stands included large diameter sapling/pole (<22.9 cm diameter at breast height [dbh]) stands and mature (>22.9 cm dbh) stands, all with overstory canopy cover between 46% and 70%. The sizes and spacing of trees in harvested stands represented the long-term desired future condition of ponderosa pine stands managed for timber production (Black Hills National Forest, Land and Resource Management Plan, 1983, Custer, SD). Unharvested stands were mature and old-growth (many large trees with a multilayered canopy) stands with >70% overstory canopy cover. Both harvested and unharvested stands often contained small aspen/birch inclusions and/or bur oak understories, although these deciduous components were more likely to be found in unharvested stands.

We selected stands from forest inventory data and 1:24,000 aerial photographs and verified the forest characteristics in the field. Of the 20 harvested stands, four were sapling/pole and 16 were mature. Six of the unharvested stands were classified as oldgrowth and 14 were classified as mature. Stand boundaries were delineated using roads, vegetation type-change boundaries, or a consistent change in overstory canopy closure. Stands varied in size from 4 to 50 ha.

We established two to five bird count points in each stand depending on stand size and shape (larger stands usually had more points). A total of 60 points were established in each harvested and unharvested treatment group. Points were >100 m from the stand boundaries and usually 250 m apart to reduce the influences of edge on bird counts and to reduce the chances of double counting birds (Ralph et al. 1993). In 6 of the smallest stands we were not able to locate points 250 m apart, but maintained as much separation as possible while still keeping at least a 100 m distance from stand boundaries. Points were marked with steel posts and were approached from the same direction during each count period.

Bird Counts

We counted birds in May and June of 1993 and 1994. Bird counts were conducted on two successive days at each point twice in 1993 and three times in 1994 (poor weather limited the number of counts in 1993) for a total of 10 visits per point. The order that stands were surveyed was reversed daily to account for hourly variations in species detectability. Counts began 1/2 hour before sunrise and were completed before 1100. We recorded the number, sex (male, female, or unknown), distance from the point, method of detection (sighting or heard song or call), and activity of all birds seen or heard during an 8-minute time period which began upon arrival at the point (Manuwal and Carey 1991). Birds flushed near the point as the observer approached were also recorded. Some stands included small (< 0.5 ha) patches of deciduous trees in the overstory; birds that were detected in these patches were recorded as out of the ponderosa pine habitat. Counts were not conducted during periods of moderate to heavy rain or heavy fog, when winds were >10 km/hr, or when temperatures were <7 or >24°C (Manuwal and Carey 1991). We attempted to minimize observer bias by using the same two trained observers throughout the study, and by alternating stands counted by each observer on consecutive days.

Analyses

We summarized abundance data of all nongame bird species using only observations of birds ≤70 m from the count point. Abundance per unit area at intervals of distance to 100 m declined for the most common species beyond 70 m. We determined daily abundance of each bird species in stands by averaging across successive days (n = 2), two-day visits per year (n = 2 in 1993 and n = 3 in 1994), and years (n = 2) for each point, and then averaging across the number of points in stands (n = 2, 3, 4, or 5). We differentiated between monomorphic and dimorphic bird species (n = 2, 3, 4, or 5). We differentiated between monomorphic and dimorphic bird species by determining which species had more males than females or individuals of unknown sex. If males outnumbered females and unknowns, the species was classified as dimorphic. A species was categorized as monomorphic if the number of females and unknowns was greater than the number of males detected. We assumed that all sexually dimorphic males were successfully paired and tallied those species' abundances as 2X the number of males (Mayfield 1981). Abundances of monomorphic species were tallied as the sum of all male, female, and unknown sex observations. Birds occurring in <5 stands over the duration of the study were not included in statistical analyses. Juveniles of all bird species were also omitted from analyses. Red crossbills (*Loxia curvirostra*), which fledged before we started our counts in May, were included only in calculations of species richness because of the difficulty in differentiating adults from juveniles. Although abundance was calculated within fixed plots of 70 m radius, these data do not represent density estimates. Precise estimates of density are not necessary for habitat studies (Verner 1985). Bird species richness was calculated as the total number of species, including game species, observed in stands.

We tested for normality and homogeneity of variance in the bird abundance data and found that neither of these assumptions for parametric statistics was met. We used an independent-sample t-test for unequal variances to test hypotheses that average abundance of birds and bird species richness were not equal between harvested and unharvested stands. We used a multi-response permutation procedure with family-wise comparisons (Mielke 1984) to compare abundance of birds and species richness among harvested sapling/pole, harvested mature, unharvested mature, and unharvested old growth stands. Statistical significance for all tests was determined at $\alpha \leq 0.10$ to reduce the ecological and management implications of failing to reject the null hypothesis when it is false (e.g., Steidl et al. 1997).

RESULTS

A total of 39 vegetation variables were analyzed for differences between treatments. Differences for 16 of the most prominent vegetation variables are summarized in Table I. Ponderosa pine density ($P < 0.01$), basal area ($P < 0.0l$), crown volume ($P < 0.01$) and percent canopy cover ($P = 0.01$) were lower in harvested stands than in unharvested stands. Several ground cover characteristics showed significantly higher values in harvested stands than unharvested stands. Total ground cover ($P = 0.03$), total grass cover ($P = 0.0l$), and foliage height density between 0.0.5 m ($P < 0.01$) were higher in harvested stands than in unharvested stands. Harvested stands also had more ($P < 0.01$) large and small logs than unharvested stands. The density of large (> 25 cm) pine snags was higher ($P < 0.01$) in unharvested stands than in harvested stands. Unharvested stands also had more ($P \leq 0.05$) bur oak than did harvested stands. A more detailed summary of vegetation characteristics is provided in Dykstra (1996).

Forty seven bird species were observed within 70 m of bird count points. The most common species were red-breasted nuthatches *(Sitta canadensis)* and yellow-rumped warblers *(Dendroica coronata),* observed at all of the points. Black-capped

Table 1. Differences in average values between treatments for 16 vegetation variables on bird study stands in the northern Black Hills, 1993-1994[1].

Stands	Harvested Stands		Unharvested	
	±	SE	±	SE
Pine DBH (cm)	23.4	0.76	22.2	0.58
Pine Basal Area (m^2/ha)	15.9	0.63a	28.1	0.98b
Pine Density (stems/ha) .	378.6	42.82a	647.9	39.39b
Aspen Density (stems/ha)	39.5	15.15	45.3	9.22
Oak Density (stems/ha)	36.0	16.48a	117.0	33.36b
Pine Crown Volume (m^3/ha)	53303.6	3447.10a	90740.7	2957.21b
Deciduous Crown Volume (m^3/ha)	1007.1	300.75	1673.9	321.57
Canopy Cover (%)	43.0	1.83a	67.7	2.06b
Large Snag (≥ 25 cm) DBH	23.4	2.69	26.4	2.33
Large Snag Density	9.1	1.65a	17.2	2.50b
Small Log (2.5 - 7.6 cm) Cover (%)	4.2	0.23a	2.9	0.18b
Large Log (≥ 7.7 cm) Cover (%)	6.1	0.47a	3.7	0.41 b
Total Ground Cover (%)	46.2	2.13a	40.1	1.87b
Total Grass Cover (%)	10.1	0.89a	6.0	0.50b
Total Forb Cover (%)	28.6	1.32	28.2	1.22
Foliage Ht. Density (0 - 0.5 m)	3.6	0.19a	2.6	0.18b

Values followed by different letters are statistically different at P = 0.10. Values followed by no letter are not statistically different.

chickadees *(Parus atricapillus),* warbling vireos *(Vireo gilvus),* and dark-eyed juncos *(Junco hyemalis)* were also common, occurring on more than 90% of the points. Twenty-nine nongame bird species were detected in five or more stands and analyzed for differences in abundance. Hairy woodpeckers *(Picoides villosus)* (*P* = 0.03), western wood-pewees *(Contopus sordidulus)* (*P* = 0.02), Townsend's solitaires *(Myadestes townsendi)* (*P* = 0.04), American robins *(Turdus migratorius)* (*P* < 0.01), chipping sparrows *(Spizella passerina)* (*P* < 0.01), and dark-eyed juncos (*P* < 0.01) were more abundant in harvested stands than unharvested stands (Table 2). Red-breasted nuthatch (*P* = 0.03), ovenbird *(Seiurus aurocapillus)* (*P* < 0.01), and black-headed grosbeak *(Pheucticus melanocephalus)* (*P* = 0.10) were more abundant in unharvested stands than harvested stands.

When we evaluated bird abundance differences among the four seral stages (harvested sapling/pole, harvested mature, unharvested mature, and old-growth), the patterns exhibited between harvested and unharvested stands were no longer evident for hairy woodpeckers, red-breasted nuthatches, and black-headed grosbeaks. Twelve species, 41% of those analyzed, differed when the four seral stages within harvested and unharvested stands of ponderosa pine were considered. For six species, the differences noted were refinements of the previous t-test between harvested and unharvested treatments. However, for six other species, northern flickers *(Colaptes auratus),* black-backed woodpeckers *(Picoides arcticus),* brown creepers *(Cetthia americana),* white-breasted nuthatches *(Sitta carolinensis),* solitary vireos (*Vireo solitarius),* and yellow-rumped warblers, differences that were not apparent between treatments became evident in the analyses of seral stages. Northern flickers were absent from sapling/pole harvested stands and most abundant (*P* < 0.01) in harvested mature stands. Black-backed woodpeckers *(Picoides arcticus)* were more abundant (*P* < 0.01) in harvested sapling/pole stands than harvested mature or unharvested mature stands. Brown creepers were more abundant (*P* ≤ 0.07) in old-growth than in any of the other three seral stages analyzed. More white-breasted nuthatches (P = 0.01) were detected in harvested mature than in unharvested mature stands. Harvested sapling/pole stands had more solitary vireos (*P* = 0.07) than harvested mature stands; solitary vireos were absent from old-growth stands. Yellow-rumped warblers were more abundant (P = 0.01) in harvested sapling/pole stands than harvested mature stands. No differences were apparent for bird species richness among seral stages.

Although not included in the abundance analyses because of limited data, three accipiters were only observed in unharvested stands: northern *goshawks (Accipiter gentilis)* in three stands, sharp-shinned hawks *(Accipiter striatus)* in three stands, and Cooper's hawks *(Accipiter cooperi)* in one stand. Three species were observed only in harvested stands: red-tailed hawks *(Buteo jamaicensis)* (three stands), common nighthawks *(Chordeiles minor)* (two stands), and downy woodpeckers *(Picoides pubescens)* (two stands).

Table 2. Average abundance of birds, and bird species richness, between harvested and unharvested stands and among seral stages of ponderosa pine in the northern Black Hills, 1993 - 1994[1].

	Harvested Stands						Unharvested Stands							
Sapling/pole	Mature		Total		Mature		Old-Growth		Total					
Species	x	SE	x	SE	x	SE	x	SE	x	SE	x	SE		
Northern goshawk	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01		
Northern flicker	0.00	0.00ab	0.04	0.01a	0.03	0.01	0.02	0.02b	0.01	0.01ab	0.01	0.01		
Yellow-bellied sapsucker	0.01	0.01	0.03	0.01	0.02	0.01	0.02	0.01	0.03	0.02	0.02	0.01		
Red-naped sapsucker	0.00	0.00	0.01	0.01	0.01	<0.01	0.01	<0.01	0.04	0.03	0.02	0.01		
Hairy woodpecker	0.08	0.03	0.06	0.01	0.06	0.01a	0.04	0.01	0.04	0.02	0.03	0.01b		
Black-backed woodpecker	<0.01	0.06	0.03ac	0.00	0.00b	0.01	0.01	<0.01	<0.01b	0.01	0.01bc	<0.01		
Western wood-pewee	0.10	0.06a	0.07	0.03a	0.07	0.02a	0.00	0.00b	0.01	0.01ab	<0.01	<0.01b		
Dusky flycatcher	0.00	0.00	0.03	0.01	0.02	0.01	0.03	0.01	0.02	0.01	0.03	0.03		
Western flycatcher	0.05	0.04	0.02	0.01	0.03	0.02	0.04	0.02	0.01	0.01	0.03	0.01		
Gray jay	0.08	0.03	0.10	0.02	0.09	0.03	0.11	0.02	0.22	0.06	0.13	0.03		
Black-capped chickadee	0.24	0.05	0.25	0.03	0.26	0.03	0.26	0.03	0.24	0.05	0.24	0.03		
Brown creeper	0.00	0.00a	<0.01	<0.01a	<0.01	<0.01	0.01	0.01a	0.12	0.04b	0.04	0.02		
White-breasted nuthatch	0.03	0.02ab	0.08	0.02a	0.06	0.01	0.02	0.01b	0.04	0.03ab	0.03	0.02		
Red-breasted nuthatch	0.38	0.05	0.45	0.04	0.43	0.03a	0.55	0.04	0.58	0.07	0.54	0.04b		
Ruby-crowned kinglet	0.00	0.00	0.01	0.01	<0.01	<0.01	0.02	0.01	0.01	0.01	0.02	<0.01		
Mountain bluebird	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.01	<0.01	<0.01		
Townsend's solitaire	0.23	0.08a	0.16	0.02a	0.17	0.03a	0.07	0.03b	0.10	0.04ab	0.09	0.03b		

Table 2. continued.

American robin	0.18	0.05ab	0.19	0.04a	0.19	0.03a	0.09	0.02bc	0.05	0.01c	0.07	0.02b
Solitary vireo	0.08	0.03a	0.03	0.02bc	0.04	0.01	0.07	0.02ac	0.00	0.00b	0.04	0.02
Warbling vireo	0.06	0.03	0.23	0.04	0.17	0.03	0.21	0.05	0.16	0.06	0.20	0.04
Yellow-rumped warbler	1.34	0.15a	0.79	0.07b	0.86	0.09	0.87	0.10ab	0.99	0.14ab	0.86	0.11
Ovenbird	0.04	0.03ac	0.08	0.03a	0.08	0.04a	0.38	0.08bd	0.33	0.11cd	0.35	0.08b
Black-headed grosbeak	0.00	0.00	0.00	0.00	0.00	0.00a	0.03	0.01	0.00	0.00	0.02	0.01b
Chipping sparrow	0.32	0.06a	0.31	0.05a	0.14	0.05a	0.11	0.03b	0.02	0.01b	0.09	0.03b
Dark-eyed junco	0.86	0.14ac	0.77	0.06a	0.76	0.07a	0.38	0.04b	0.48	0.08bc	0.40	0.05b
Brown-headed cowbird	0.13	0.06	0.10	0.02	0.10	0.03	0.11	0.03	0.07	0.02	0.10	0.02
Western tanager	0.21	0.06	0.20	0.04	0.21	0.04	0.12	0.02	0.16	0.05	0.14	0.03
Pine siskin	0.03	0.02	0.03	0.01	0.03	0.01	0.05	0.02	0.04	0.02	0.05	0.02
Species richness	16.00	0.71	17.44	0.76	17.20	0.63	16.00	0.97	16.17	1.22	16.00	0.75

[1] Averages of harvested sapling/pole, harvested mature, unharvested mature, and unharvested old-growth followed by different letters are statistically different at P = 0.10, MRPP test. Averages of harvested total and unharvested total followed by different letters are statistically different P = 0.10, separate variance estimate t-test.

DISCUSSION

Timber harvest in Black Hills ponderosa pine stands decreased canopy closure, crown volume, and tree density, and increased total understory vegetative cover, grass cover, and foliage height density <0.5 m tall (Table 1). Understory plants uncommon or absent from unharvested stands are more abundant in stands where tree basal area and canopy closure have been reduced (Uresk and Severson, in press).

Open stand conditions created by timber harvest benefitted several bird species. Early AND mid-seral species such as Townsend's solitaires, chipping sparrows, American robins, and dark-eyed juncos that feed or nest on the ground were more abundant in harvested stands. Open stand characteristics apparently provided better nesting cover and foraging opportunities for these bird species. Thinning of residual sapling/pole trees often follows commercial harvest of mature pine forests in the Black Hills. Thinning promotes rapid growth of larger trees (Boldt and Van Duesen 1974), and increases woody debris on the ground. We observed more northern flickers and black-backed woodpeckers in harvested stands and believe that an increased abundance of woody debris produced by thinning provided foraging sites for these species (see Thomas 1979). Other species (e.g., western wood-pewee) that were more common in harvested stands may have preferred the degree or uniformity of openness (Mannan and Meslow 1984). The cumulative effects of harvesting timber more than likely increased food resources, especially seeds and insects, by increasing the amount of understory vegetation and down woody material over that which existed in unharvested stands. Food availability may be the most important source of variation in explaining responses of birds to vegetative manipulations (Brush and Stiles 1 986).

Structural changes to the forest following timber harvest lead to declines in birds preferring dense vegetation (Mannan and Meslow 1984). In the Black Hills, species that prefer dense stands of trees (e.g., red-breasted nuthatches, ovenbirds, black-headed grosbeaks) were less abundant in harvested than in unharvested stands. Ovenbirds and black-headed grosbeaks may have been responding to the greater understory deciduous tree component in unharvested stands than existed in harvested stands. Resident birds such as red-breasted nuthatches and brown creepers are affected more by the loss of unharvested forests in the Rocky Mountains than migrant birds (Hejl et al. 1995). Large pine snags in our study area were sometimes felled during the timber harvest process or removed for firewood. Timber harvest also reduced the density of large trees (e.g., > 38 cm dbh). We found that brown creepers, which occurred mostly in old-growth stands, were the only species to exhibit a preference for stands with large snags and large trees. Other cavity-nesting species (i.e. black-backed woodpecker, white-breasted nuthatch) seemed to choose habitat factors beyond just the abundance of large snags, as many of them were more abundant in harvested stands, which had fewer large snags than unharvested areas.

Although there were alterations in the abundance and occurrence of birds because of timber harvest, we did not note any differences in the number of species in the Black Hills. The few species that disappeared from stands following timber harve were replaced by other species.

CONCLUSIONS

Timber harvest and the resulting changes in forest conditions altered bird populations and communities in ponderosa pine stands in the Black Hills. The long-term desired future condition of harvested stands enhanced habitat conditions for ground nesting and foraging birds, and those preferring open forest canopies. Birds that declined in abundance in harvested stands included red-breasted nuthatches, ovenbirds, and black-headed grosbeaks. Brown creepers preferred unharvested old-growth stands. Most forested stands in the Black Hills National Forest have been harvested over the past 40 years; only 12% of stands have not been harvested during that period (1993 unpublished data, Black Hills National Forest, Custer, South Dakota). The Black Hills National Forest Land and Resource Management Plan (1983) specifies that 5% of the land base will be managed for old-growth but does not include guidelines for maintaining a percentage of ponderosa pine stands in any other particular seral stage. Thus, the amount of forest resembling but not designated as old-growth could conceivably be reduced under current management direction. Bird species associated with dense forest conditions will decline in abundance if a higher proportion of these stands are harvested.

ACKNOWLEDGMENTS

Funding for this project was from the U.S. Forest Service, Rocky Mountain Experiment Station, Black Hills National Forest, South Dakota Department of Game, Fish, and Parks, and U.S. Fish and Wildlife Service. This work was accomplished while the senior author was on leave of absence from Black Hills National Forest. S. H. Anderson, J. R. Squires, C. McCarthy, and two anonymous reviewers provided comments to earlier drafts of this manuscript.

LITERATURE CITED

Boldt, C. E., and J. L. Van Duesen. 1974. Silviculture of ponderosa pine in the Black Hills: the status of our knowledge. USDA, For. Serv. Res. Paper RM-124. Rocky Mtn. For. Range Exp. Stn., Fort Collins, CO.

Brush, T., and E. W. Stiles. 1986. Using food abundance to predict habitat use by birds. Pages 57-63 *in* J. Verner, M. L. Morrison, and C. J. Ralph, eds. Wildlife 2000: Modeling habitat relationships of terrestrial vertebrates. Univ. of Wisconsin Press, Madison.

Dykstra, B. L. 1996. Effects of harvesting ponderosa pine on birds in the Black Hills of South Dakota and Wyoming. M. S. thesis. South Dakota State Univ., Brookings.

Franklin, J. F., and R. T. T. Forman. 1987. Creating landscape patterns by forest cutting: Ecological consequences and principles. Landscape Ecol. 1:5-1 8.

Freemark, K. E., and H. G. Merriam. 1986. Importance of area and habitat heterogeneity to bird assemblages in temperate forest fragments. Biol. Conserv. 36:115-141.

Hejl, S. J., R. L. Hutto, C. R. Preston, and D. M. Finch. 1995. Effects of silvicultural treatments in the Rocky Mountains. Pages 220-244 *in* T. E. Martin and D. M.

Finch, eds. Ecology and management of neotropical migratory birds: a synthesis and review of critical issues. Oxford University Press. New York.
Hoffman, G. R., and R. R. Alexander. 1987. Forest vegetation of the Black Hills National Forest of South Dakota and Wyoming: a habitat type classification. USDA, For. Serv. Res. Paper RM-276. Rocky Mtn. For. and Range. Exp. Stn., Fort Collins, CO.
James, F. C., and N. 0. Warner. 1982. Relationships between temperate forest bird communities and vegetation structure. Ecology 63: 159-171.
Lord, J. M., and D. A. Norton. 1990. Scale and the spacial concept of fragmentation. Conserv. Biol. 4: 197-202.
MacArthur, R. H., and J. W. MacArthur. 1961. On bird species diversity. Ecology 42:594-598.
Mannan, R. W., and E. C. Meslow. 1984. Bird populations and vegetation characteristics in managed and old-growth forests, northeastern Oregon. J. Wildl. Manage 48: 1219-I238.
Manuwal, D. A., and A. B. Carey. 1991. Methods for measuring populations of small diurnal forest birds. USDA, For. Serv. Gen. Tech. Rep. PNW-GTR-278. Pacific Northwest Res. Stn., Portland, OR.
Mayfield, H. F. 1981. Problems in estimating population size through counts of singing males. Studies in avian biology 6:220-224.
Mielke, P. W. 1984. Meteorological applications of permutation techniques based on distance functions. Handbook of statistics 4:813-830.
Orr, H. K. 1975. Watershed management in the Black Hills: the status of our knowledge. USDA, For. Serv. Res. Paper RM-141. Rocky Mtn. For. Range Exp. Stn., Fort Collins, CO.
Probst, J. R., and T. R. Crow. 1991. Integrating biological diversity and resource management. J. For. 89(2):12-17.
Ralph, C. J., G. R. Geupel, P. Pyle, T. E. Martin, and D. F. DeSante. 1993. Handbook of field methods for monitoring landbirds. USDA, For. Serv. Gen. Tech. Rep. PSW-GTR-144. Albany, CA.
Ripple, W. J., G. A. Bradshaw, and T. A. Spies. 1991. Measuring forest landscape patterns in the Cascade Range of Oregon, USA. Biol. Conserv. 57:73-88.
Rotenberry, J. T. 1985. The role of habitat in avian community composition: physiognomy or floristics? Oecologia 67:213-217.
Steidl, R. J., J. P. Hayes, and E. Schauber. 1997. Statistical power analysis in wildlife research. J. Wildl. Manage. 61:270-279.
Szaro, R. C., and R. P. Balda. 1979. Bird community dynamics in a ponderosa pine forest. Studies in avian biology no. 3. Cooper Ornithological Society.
Thomas, J. W. 1979. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. U. S. Dept. Agric., For. Serv. Handbook No. 553. U. S. Government Printing Office, Washington, D.C.
Uresk, D. W., and K. E. Severson. In press. Response of understory species to changes in ponderosa pine stocking levels in the Black Hills. Great Basin Nat.
Verner, J. 1985. Assessment of counting techniques. Pages 247-302 *in* R. F. Johnston, ed. Current Ornithology: Vol. 2. Plenum Press. NY.

FIRST BIENNIAL NORTH AMERICAN FOREST ECOLOGY WORKSHOP

JUNE 24-26, 1997

NORTH CAROLINA ST. UNIV.

RALEIGH, NC

WORKSHOP WAS ORGANIZED

UNDER THE AUSPICES OF THE:

FOREST ECOLOGY WORKING GROUP,

SOCIETY OF AMERICAN FORESTERS

J. E. COOK and B. P. OSWALD, COMPILERS