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A COMPARISON OF ON- AND OFF-ROAD BIRD COUNTS: DO YOU NEED TO GO OFF ROAD TO COUNT BIRDS ACCURATELY?

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Abstract.—On- and off-road point counts were established in two National Forests in northern Minnesota to determine whether breeding bird parameters derived from two different types of counts conducted on- or off-road were comparable. The first design compared single-year counts randomly placed along a road (like the U.S. Fish and Wildlife Service Breeding Bird Survey) and counts conducted at least 200 m from the road that were placed in a specific habitat. In the second approach, differences and similarities were examined in data gathered over 3 yr from points placed near roads to points in the same habitat (stand) >200 m from the road. Data from the first approach indicated that on average, two more species and four more individuals were observed on roadside counts than on off-road counts. Twenty-four individual species were more abundant on road than off road. Many of these species were ones associated with openings or shrubs that develop along roads. Of the five species that were more abundant on the off-road counts, three had specific associations with lowland conifer habitat, which was not as commonly sampled with the on-road counts. Data from the second approach indicated that number of species, individuals, and individual species-abundance patterns were similar between the paired within-stand points. Greater statistical power was achieved for data gathered with habitat specific counts off-road primarily because standard errors were lower for bird parameters in this data set than in the data collected on road. It is suggested that points can be placed on roads with the restriction that points be selected randomly and placed within distinct habitat types, and that roads selected for sampling have a closed canopy. Evidence provided here also suggest that some points be placed off road in habitats not sampled with on-road counts.

UNA COMPARACIÓN DE CONTEOS DENTRO-DE Y FUERA-DE CAMINOS: ¿HAY QUE ALEJARSE DE LOS CAMINOS PARA CONTAR AVES CON EXACTITUD?

Sinopsis.—Se establecieron lugares para hacer conteos puntualizados dentro-de y fuera-de caminos en dos bosques nacionales en el norte de Minnesota para determinar si los parámetros usados para aves que anidan derivados de dos tipos de conteos diferentes eran comparables dentro-de y fuera-de caminos. El primer diseño comparó conteos de un año colocados al azar através de un camino (similar al muestreo que el Servicio Federal de Pesca y Vida Silvestre produce con aves que anidan) y contajes conducidos al menos 200 m del camino que fueron localizados en un habitat específico. En el segundo enfoque, las diferencias y similitudes se examinaron en los datos obtenidos por más de 3 años en puntos localizados cerca de caminos con datos de puntos localizados en el mismo habitat (plantación) >200 m del camino. Datos del primer enfoque indican que se observan dos especies más y cuatro individuos más en promedio en los caminos que fuera de ellos. Veinticuatro especies fueron más abundantes en los caminos que fuera de ellos. Muchas de estas especies estaban asociadas con aperturas o con arbustos que crecen al borde de los caminos. De las cinco especies más abundantes fuera de los caminos, tres tenían asociaciones específicas con habitat de coníferas de bajura, lo cual no era comunmente muestreado en los conteos dentro de caminos. Datos del segundo enfoque indican que el número de especies, individuos, y patrones individuales de abundancia de especies son similares entre los puntos pareados dentro de la plantación. Se obtuvo un mayor poder estadístico para los datos obtenidos con

contajes fuera de caminos en habitats específicos debido a que los errores estandard fueron menores para los parámetros de aves en este conjunto de datos en contraste con los datos obtenidos en el camino. Se sugiere que los puntos se pueden colocar en caminos con la restricción de que los puntos se deben seleccionar al azar y colocarse dentro de tipos de habitat diferentes y que los caminos seleccionados para muestreo tengan un dosel cerrado. La evidencia aquí provista sugiere que se coloquen algunos puntos fuera de los caminos en habitats no muestreados con los conteos dentro de los caminos.

With the increased interest and awareness of the status of neotropical migrant birds in the United States, several organizations have developed strategies to monitor abundance of these species (see Finch and Stangel 1993). The monitoring task group of the National Fish and Wildlife Foundation's Neotropical Migratory Bird Conservation Program recently developed guidelines for three levels of bird monitoring that each National Forest should establish within the next 3 yr (Manley and Monitoring Task Group 1993). Their recommendations were based on papers published in a proceedings (Ralph et al. 1994) and monitoring guidelines (Ralph et al. 1993). These documents suggest that National Forests establish monitoring programs for neotropical migrants and that monitoring should be done in specific habitats. Current guidelines suggest that two-thirds of points established in the monitoring should be placed along secondary and tertiary roads and that one-third of the points should be placed off-road in habitats not sampled with the roadside counts. These guidelines are based on the premise that bird monitoring conducted along roads provides the same results as a monitoring program that is established off of roads. With the exception of studies conducted by Hutto et al. (1994), however, there have been no published studies that have compared counts or trends of bird populations based on on-road versus off-road counts. With the potential monetary resources that may be invested in monitoring, it is imperative to identify the limitations and merits of different sampling regimes.

Our objectives were to compare two separate sets of bird data collected on- and off-road, each set derived from a different study design. The first approach was to determine whether counts of breeding birds from randomly selected points along roads not in specific habitat types (like the Breeding Bird Survey [BBS]) were similar to counts conducted at least 200 m from a road. The second study design compared 3-yr trends in bird abundance patterns between counts conducted along roads and counts in the same habitat >200 m from the road. This study design is comparable to those conducted by others (see Ralph et al. 1994), with the exception that results presented here are from 3 yr of data, whereas previous studies were conducted in 1 yr only. In addition to comparing bird counts from these two methods of monitoring, we calculated the power of the statistical analyses for on- and off-road counts with a variety of sample sizes to recommend minimum numbers of counts required to detect specified differences in bird abundance pàtterns. We did these calculations with each of the two different methods to determine if the

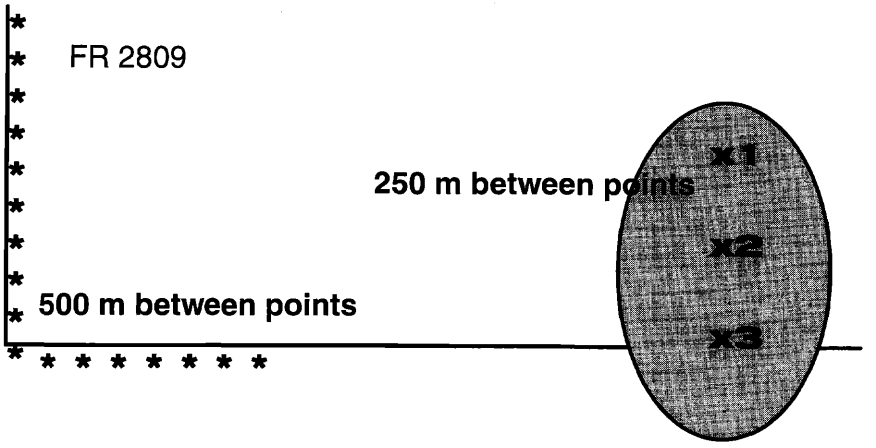

FIGURE 1. Schematic of study design where the stars represent one randomly located roadside count with 17 stops and the shaded area represents a forest stand where three point counts were placed. Statistical comparisons were done separately between the on-road counts and points x1 and x2, and between x3 and x1 (paired comparisons).

cost of implementing a monitoring program would be comparable with the two different approaches.

METHODS

Study areas.—Data for on- and off-road comparisons were collected in two National Forests in Minnesota where we had established habitat specific bird monitoring programs (see Hanowski and Niemi 1994). The Chippewa National Forest is located in the north central portion of the State, and the Superior National Forest in the northeast region. Major habitat types are similar within each Forest except that upland spruce-fir (*Picea* spp. and *Abies balsamea*) forests are more common in the Superior National Forest. See Hanowski and Niemi (1994) for detailed description of study areas and site selection.

On-road points.—To address our first objective, we established 20 roadside routes on forest roads (gravel with no maintained shoulder or ditch and a closed canopy over the road), 10 within each forest. The routes and direction of travel along each roadside route were randomly selected from possible forest routes that were within the vicinity of our off-road monitoring points. Seventeen stops were completed on each route, each 500 m apart, for a total of 340 counts along roads (Fig. 1). These points were not placed in specific habitat types, and thus represent sampling comparable to the BBS in which sample routes are randomly selected and counts are conducted at 800 m intervals. These roadside counts were compared to data collected in specific stands that were defined by habitat type where points were placed at least 200 m from the road (see below).

Off-road points.—We used data from counts completed for our habitat-

specific bird monitoring programs in each forest to address our first and second objectives. This program was designed to sample stands >15 ha within specific habitat types (see Hanowski and Niemi 1994). A 15 ha stand was required because we subsampled each stand by conducting three counts in each stand. As we subsampled stands, and several stands were sampled (140 in the Chippewa and 160 in the Superior), there were many stands (n = 93) in which one point was located adjacent to a forest service road (open to travel) or access roads (not open to vehicle travel) and another point in the same stand was at least 200 m from the road (Fig. 1). Habitat-specific counts off road were used in the comparison with the on-road surveys (above) and 186 points (93 pairs) were used for the paired on-road and off-road analyses.

Bird counts.—We conducted one bird count (10 min in duration) at each point during the breeding season. The counts were conducted by six trained observers and were completed from 0.5 h before to 4 h after sunrise. Counts were conducted only during good weather (i.e., wind <24 km/h and no precipitation). Weather information (cloud cover, temperature, and wind speed) and time of day the census was conducted were recorded. All birds heard or seen from the center point were recorded in a circle with estimates of their distance from the center point (up to 100 m). Birds beyond 100 m were recorded but were not used in the analyses. Types of stands censused (forest cover type) were stratified by time of morning and observer. For example, we avoided sampling all upland pine stands early or late in the morning. Forest cover types censused also were stratified by observer; each observer sampled essentially the same number of stands in each stratum. All observers were required to go through our training and testing program (Hanowski and Niemi 1994). This included passing an aural exam of 80 species, a hearing test and field training.

Statistical analyses.—In the first approach, number of species, total number of individuals, and number of individuals for each species were compared between the randomly placed on-road and counts done in habitat stands off road with a Kruskal-Wallis ANOVA. We used this non-parametric test because we were not able to meet assumptions for a parametric test for most species (e.g., normality and homogeneity-of-variances). With the non-parametric test we were able to test for differences between on- and off-road counts for less abundant species as well as the more common species.

In the second approach (the paired within-stand data), we used a repeated measures ANOVA (BMDP Statistical Software, Inc. 1992) with two factors to test for differences and similarities in the data for 1991, 1992 and 1993. This analysis is appropriate for data that are gathered at the same points over time. The two factors in the analyses were year and paired points within a stand (on-road and off-road).

Power calculations.—Differences detectable between means were calculated for five percentages (10, 25, 50, 75 and 100) for all species detected on the two different count types (on-road [BBS type] and off-road

in specific habitats). We used means and standard errors gathered in 1991 only for the on-road data in the power analyses. For the habitat-specific paired-data comparisons, the grand mean (mean of yearly untransformed means from 1991, 1992, and 1993) was used. Power was calculated for all species observed regardless of their relative abundance. We calculated the power of statistical analyses with the software package SOLO Power Analyses (BMDP Statistical Software, Inc. 1992). For all calculations, we used an alpha of 0.05 (Type I error) and set the power for determining percent detectability at 0.80 (Type II error).

RESULTS

On- (BBS like) and off-road comparisons.—A total of 99 species was observed on both the on- and off-road counts. Of these, four were observed only on the off-road counts and 18 were counted only on the roadside counts (Table 1). With the exception of the Palm Warbler (see Tables 1 and 2 for scientific names), most species seen only off-road were observed on only one or two counts. Many of the species observed only on roads including the American Bittern, Great Blue Heron, Mallard, Common Snipe, Gray Catbird, and LeConte's Sparrow (Table 1) were associated with wetlands.

On average, 2.5 more species and 3.5 more individuals ($P < 0.0001$) were observed on roadside counts than on off-road counts (Table 2). Individuals of species that have an association with edge habitat were more commonly found along roads ($P < 0.01$) and the increase in numbers of these individuals contributed significantly to the additional species and individuals found along roads in comparison with counts done off-road. For example, on average 5.6 of the individuals counted on roadsides have edge associations compared with 2.5 individuals with edge associations that were counted off-road. No significant difference ($P = 0.43$) was found in the number of individuals that are associated with forest habitat between the on- and off-road counts.

On a species level, 24 were significantly more abundant on roads than off roads; only five species were significantly more abundant off roads than on roads (Table 2). Of the species that were more abundant on roads, many can be classified as associated with edges (Blue Jay, American Crow, American Robin, Gray Catbird, Cedar Waxwing, Chestnut-sided Warbler, Mourning Warbler, Common Yellowthroat, Chipping Sparrow, Song Sparrow, Brown-headed Cowbird and American Goldfinch). Three of five species that were more abundant off roads than on roads, Yellow-bellied Flycatcher, Golden-crowned Kinglet and Connecticut Warbler have associations with lowland conifer habitats.

Paired within-stand comparisons.—Ninety-eight species were observed on the paired within-stand counts over a 3-yr period. Fifteen species were counted only on points on the road and nine species were observed only on points >200 m from the road (Table 1). Of species that were observed either exclusively on the road or >200 m off the road, only the Pileated

TABLE 1. Number of points at which a species was recorded only on-road or off-road, or only on points paired within-stand on the road or >200 m from a road.

Species	On road	Off road	Paired within-stand on road	Paired within-stand off road
American Bittern *Botaurus lentiginosus*	5	0	1	0
Great Blue Heron *Ardea herodias*	3	0	—	—
Mallard *Anas platyrhynchos*	2	0	—	—
Blue-winged Teal *Anas discors*	—	—	0	1
Bald Eagle *Haliaeetus leucocephalus*	1	0	0	1
Sharp-shinned Hawk *Accipiter striatus*	0	1	—	—
Cooper's Hawk *Accipiter cooperii*	—	—	1	0
American Kestrel *Falco sparverius*	1	0	—	—
Spruce Grouse *Dendragapus canadensis*	—	—	1	0
Common Snipe *Gallinago gallinago*	4	0	2	0
American Woodcock *Scolopax minor*	—	—	1	0
Mourning Dove *Zenaida macroura*	1	0	—	—
Barred Owl *Strix varia*	—	—	1	0
Great Gray Owl *Strix nebulosa*	0	1	0	1
Belted Kingfisher *Ceryle alcyon*	1	0	0	1
Black-backed Woodpecker *Picoides arcticus*	—	—	1	0
Pileated Woodpecker *Dryocopus pileatus*	—	—	0	4
Eastern Phoebe *Sayornis phoebe*	—	—	2	0
Tree Swallow *Tachycineta bicolor*	2	0	—	—
Cliff Swallow *Hirundo pyrrhonota*	1	0	—	—
Common Raven *Corvus corax*	—	—	2	0
Boreal Chickadee *Parus hudsonicus*	0	2	1	0
House Wren *Troglodytes aedon*	—	—	2	0
Sedge Wren *Cistothorus platensis*	—	—	2	0
Eastern Bluebird *Sialia sialis*	1	0	0	1

TABLE 1. Continued.

Species	On road	Off road	Paired within-stand on road	Paired within-stand off road
Gray Catbird				
Dumetella carolinensis	14	0	—	—
Brown Thrasher				
Toxostoma rufum	—	—	2	0
Cape May Warbler				
Dendroica tigrina	1	0	—	—
Palm Warbler				
Dendroica palmarum	0	9	0	2
Clay-colored sparrow				
Spizella pallida	—	—	1	0
Vesper Sparrow				
Pooecetes gramineus	1	0	—	—
Savannah Sparrow				
Passerculus sandwichensis	2	0	—	—
LeConte's Sparrow				
Ammodramus leconteii	3	0	1	0
Dark-eyed Junco				
Junco hyemalis	—	—	0	3
Bobolink				
Dolichonyx oryzivorus	1	0	—	—
Yellow-headed Blackbird				
Xanthocephalus xanthocephalus	1	0	—	—

Woodpecker occurred on more than three points (four points >200 m from road counts).

Unlike the large number of differences found in the above comparison of on- and off-road counts, no differences were found for number of individuals, or for number of edge and forest birds, between the paired points within a stand over a 3-yr period. Only one species, the Canada Warbler, showed a significant difference in the paired points comparison (Table 3). Even for this species, however, a clear pattern was not evident over years, indicating that it was not consistently more abundant on the road or off the road. For example, mean number observed in 1991 was the same for paired points within a stand, number observed was higher on points >200 m from the road in 1992, and number observed higher on the points closer to the road in 1993. Eight species varied significantly among years and eight species had a significant interaction (year and road position) (Table 3). A significant interaction occurred when a given species was more abundant in one group (e.g., off-road) in 1 yr, but then was more abundant in the other group (e.g., on-road) in another year.

Power of analyses.—Percent of all species for which we could detect a 10–100% difference in abundance with different numbers of counts were similar between the two contrasted data sets used in the analyses (e.g., the on- vs. off-road [BBS like] and the paired within-stand data) (Figs. 2 and 3). For all sample sizes calculated, we could detect either a 10% or

TABLE 2. Mean, SE, and results of Kruskal-Wallis ANOVA for bird species that differed in abundance between on- (BBS like) and off-road counts.

Species	On Road		Off Road		Kruskal-Wallis	
	$\bar{x}$	SE	$\bar{x}$	SE	H'	P
Yellow-bellied Sapsucker *Sphyrapicus varius*	0.18	0.02	0.09	0.01	10.6	0.001
Northern Flicker *Colaptes auratus*	0.06	0.01	0.02	0.01	5.9	0.02
Yellow-bellied Flycatcher *Empidonax flaviventris*	0.05	0.01	0.09	0.01	4.5	0.03
Eastern Phoebe *Sayornis phoebe*	0.04	0.01	0.01	0.01	16.5	0.0001
Eastern Kingbird *Tyrannus tyrannus*	0.04	0.01	0.01	0.01	12.2	0.0005
Blue Jay *Cyanocitta cristata*	0.18	0.03	0.1	0.01	5.9	0.01
American Crow *Corvus brachyrhynchos*	0.03	0.01	0.01	0.01	10.7	0.001
Winter Wren *Troglodytes troglodytes*	0.11	0.02	0.2	0.02	13.3	0.0003
Sedge Wren *Cistothorus platensis*	0.03	0.01	0.01	0.01	7.5	0.006
Golden-crowned Kinglet *Regulus satrapa*	0.06	0.01	0.09	0.01	4.1	0.04
Veery *Catharus fuscescens*	0.59	0.05	0.48	0.03	5.2	0.02
Hermit Thrush *Catharus guttatus*	0.18	0.02	0.26	0.02	4.8	0.03
American Robin *Turdus migratorius*	0.31	0.03	0.16	0.02	17.8	0.0001
Cedar Waxwing *Bombycilla cedrorum*	0.07	0.02	0.03	0.01	7.6	0.006
Red-eyed Vireo *Vireo olivaceus*	1.28	0.05	0.91	0.04	31.9	0.0001
Yellow Warbler *Dendroica petechia*	0.06	0.02	0.02	0.01	8.6	0.003
Chestnut-sided Warbler *Dendroica pensylvanica*	1.05	0.06	0.57	0.04	56.2	0.0001
Ovenbird *Seiurus aurocapillus*	1.52	0.07	1.19	0.05	15.4	0.0001
Connecticut Warbler *Oporornis agilis*	0.02	0.01	0.1	0.02	13.6	0.0002
Mourning Warbler *Oporornis philadelphia*	0.45	0.04	0.26	0.02	16.4	0.0001
Common Yellowthroat *Geothlypis trichas*	0.51	0.04	0.23	0.02	31.2	0.0001
Rose-breasted Grosbeak *Pheucticus ludovicianus*	0.18	0.02	0.11	0.01	7.6	0.006
Chipping Sparrow *Spizella passerina*	0.43	0.04	0.09	0.01	77.8	0.0001
Song Sparrow *Melospiza melodia*	0.42	0.04	0.13	0.02	62.5	0.0001
Swamp Sparrow *Melospiza georgiana*	0.24	0.04	0.07	0.01	19.1	0.0001

TABLE 2. Continued.

Species	On Road		Off Road		Kruskal-Wallis	
	$\bar{x}$	SE	$\bar{x}$	SE	H'	P
Red-winged Blackbird *Agelaius phoeniceus*	0.16	0.03	0.02	0.01	23.4	0.0001
Brown-headed Cowbird *Molothrus ater*	0.16	0.02	0.06	0.01	24.7	0.0001
American Goldfinch *Carduelis tristis*	0.08	0.02	0.02	0.01	20.2	0.001
Total individuals	13.4	0.24	9.9	0.15	137.4	0.0001
Total species	9.2	0.15	7.2	0.11	94.7	0.0001

25% difference in means for a larger number of species using the within-stand data in comparison with calculations done with the on-road counts (Figs. 2 and 3).

DISCUSSION

For comparative reasons, results presented here can be generalized to be representative of data gathered with the BBS method (our on-road counts) or with a habitat-specific monitoring format with data from two different distances from a road (our paired on-road or >200 m from the road). As there were few differences between paired data points on- and >200 m off-road in the same stand over a 3-yr period, we limit the discussion to a comparison of our randomly placed on-road and habitat-specific off-road counts. Our data suggest that if points are to be placed in specific habitats, then points on or near the road will likely provide similar results to those points placed >200 m off-road in the same habitat. This recommendation, however, applies to narrow roads with no shoulders, ditches and developed openings with shrubs (i.e., no shoulders, no ditches and no developed openings). This situation occurs on narrow forest roads where the canopy is generally closed over the road such as the roads that were selected for this study.

The difference in number of species observed on- and off-roads can be attributed to a variety of factors. First, about half of the 3.5 (on average) more individuals and two more species observed on counts on the road were those species associated with habitats that develop along open edges. Several of the species found more commonly along roads that we sampled were likely present because of the shrubs that develop in these areas. For example, the Eastern Kingbird, Gray Catbird, Chestnut-sided Warbler, Mourning Warbler, Cedar Waxwing, Common Yellowthroat, Song Sparrow and American Goldfinch are all species that are associated with shrubs (Brewer et al. 1991). Second, several species such as the American Robin, Brown-headed Cowbird, and Chipping Sparrow that are associated with edges (Ehrlich et al. 1988) partially contributed to the higher numbers of individuals and species counted on roads. Finally, other species

TABLE 3. Mean, SE, and *P*-values from a repeated-measures ANOVA that examined differences and similarities among counts conducted within the same stand on a road and those conducted >200 m from a road from 1991 to 1993.

Species	1991				1992				1993				*P*-value		
	On road		>200 m off road		On road		>200 m off road		On road		>200 m off road				
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Time	Roads	Inter-action
Total individuals	11.01	0.34	11.24	0.37	10.32	0.40	10.18	0.40	11.97	0.33	11.49	0.37	0.0001	0.7721	0.0027
Total number species	7.80	0.27	8.10	0.27	6.77	0.30	7.06	0.29	8.70	0.32	8.23	0.28	0.0000	0.3218	0.0000
Ruffed Grouse	0.03	0.02	0.04	0.02	0.02	0.02	0.02	0.02	0.07	0.03	0.06	0.03	0.3024	0.9700	0.5241
Yellow-bellied Sapsucker	0.09	0.03	0.13	0.04	0.09	0.03	0.12	0.04	0.12	0.04	0.11	0.04	0.5116	0.9293	0.9744
Hairy Woodpecker			0.04	0.02	0.03	0.02	0.07	0.03	0.03	0.02	0.01	0.01	0.3900	0.9276	0.0414
Northern Flicker	0.01	0.01	0.03	0.02	0.06	0.02	0.03	0.02	0.03	0.02	0.03	0.02	0.9805	0.3521	0.3737
Eastern Wood-Pewee	0.23	0.05	0.26	0.06	0.08	0.03	0.10	0.03	0.10	0.04	0.15	0.05	0.2900	0.6457	0.0003
Yellow-bellied Flycatcher	0.02	0.02	0.09	0.03	0.03	0.02	0.07	0.03	0.19	0.05	0.12	0.04	0.0002	0.6090	0.1162
Alder Flycatcher	0.12	0.04	0.07	0.03	0.09	0.03	0.03	0.02	0.04	0.02	0.07	0.04	0.1261	0.7674	0.4689
Least Flycatcher	0.40	0.08	0.41	0.09	0.43	0.11	0.26	0.07	0.45	0.11	0.37	0.09	0.0998	0.4992	0.3438
Great Crested Flycatcher	0.01	0.01	0.03	0.02	0.02	0.02	0.07	0.03	0.04	0.02	0.03	0.02	0.2596	0.2665	0.3169
Gray Jay	0.03	0.02	0.02	0.02	0.01	0.01	0.02	0.02	0.03	0.02	0.12	0.07	0.2706	0.2793	0.2154
Blue Jay	0.10	0.03	0.05	0.03	0.11	0.03	0.08	0.04	0.12	0.04	0.11	0.04	0.7587	0.8400	0.0655
Black-capped Chickadee	0.07	0.03	0.07	0.03	0.04	0.02	0.08	0.03	0.14	0.06	0.23	0.06	0.0325	0.2855	0.0144
Red-breasted Nuthatch	0.05	0.02	0.02	0.02	0.03	0.02	0.04	0.02	0.14	0.05	0.07	0.03	0.5736	0.0890	0.1737
White-breasted Nuthatch	0.01	0.01	0.01	0.01	0.03	0.02	0.02	0.02	0.04	0.03			0.3409	0.5557	0.2049
Brown Creeper	0.09	0.03	0.08	0.03	0.04	0.02	0.14	0.04	0.01	0.01	0.07	0.03	0.1422	0.3215	0.0288
Winter Wren	0.11	0.03	0.16	0.04	0.11	0.04	0.12	0.04	0.21	0.05	0.23	0.05	0.1194	0.2788	0.0871
Golden-crowned Kinglet	0.07	0.03	0.05	0.02	0.03	0.02	0.09	0.04	0.10	0.04	0.08	0.03	0.2727	0.2860	0.5638
Veery	0.61	0.08	0.68	0.09	0.59	0.09	0.52	0.07	0.73	0.08	0.59	0.10	0.0419	0.3172	0.6596
Hermit Thrush	0.14	0.04	0.25	0.06	0.08	0.03	0.18	0.05	0.16	0.06	0.14	0.05	0.0261	0.8927	0.2744
American Robin	0.27	0.06	0.16	0.04	0.12	0.04	0.17	0.04	0.15	0.04	0.12	0.04	0.4525	0.0954	0.2246
Cedar Waxwing	0.01	0.01	0.07	0.03	0.04	0.03	0.07	0.03	0.06	0.04	0.04	0.03	0.3762	0.6328	0.3875
Solitary Vireo			0.03	0.02			0.02	0.02	0.07	0.03	0.07	0.04	0.0098	0.9206	0.0978
Yellow-throated Vireo	0.01	0.01	0.02	0.02	0.07	0.03	0.02	0.02	0.03	0.02	0.04	0.03	0.7790	0.1231	0.0857
Red-eyed Vireo	1.07	0.09	1.04	0.09	0.84	0.09	0.90	0.10	0.84	0.10	1.00	0.11	0.9763	0.4555	0.0047
Golden-winged Warbler	0.09	0.03	0.11	0.04	0.06	0.02	0.09	0.03	0.11	0.05	0.10	0.04	0.7047	0.7220	0.5459

TABLE 3. Continued.

Species	1991				1992				1993				*P*-value		
	On road		>200 m off road		On road		>200 m off road		On road		>200 m off road				
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Time	Roads	Interaction
Nashville Warbler	0.72	0.11	0.63	0.09	0.81	0.13	0.68	0.11	1.03	0.13	1.08	0.14	0.2894	0.7186	0.0002
Northern Parula	0.09	0.03	0.12	0.03	0.06	0.03	0.09	0.03	0.08	0.03	0.12	0.04	0.3381	0.4727	0.3497
Chestnut-sided Warbler	0.70	0.09	0.81	0.10	0.79	0.11	0.66	0.10	0.75	0.12	0.66	0.12	0.1197	0.4858	0.6462
Magnolia Warbler	0.11	0.03	0.17	0.04	0.03	0.02	0.08	0.04	0.23	0.06	0.14	0.04	0.0019	0.4029	0.0649
Yellow-rumped Warbler	0.14	0.04	0.17	0.05	0.09	0.04	0.04	0.03	0.06	0.03	0.10	0.04	0.2607	0.0717	0.1188
Black-throated Green Warbler	0.17	0.04	0.17	0.05	0.17	0.05	0.16	0.04	0.16	0.04	0.16	0.05	0.9116	0.7791	0.8720
Blackburnian Warbler	0.19	0.05	0.23	0.05	0.17	0.05	0.18	0.05	0.29	0.06	0.19	0.05	0.1177	0.4007	0.6249
Black-and-white Warbler	0.27	0.05	0.27	0.05	0.16	0.04	0.17	0.04	0.22	0.05	0.30	0.06	0.8180	0.3604	0.0281
American Redstart	0.17	0.06	0.22	0.06	0.24	0.07	0.26	0.06	0.25	0.08	0.37	0.09	0.0355	0.2944	0.2609
Ovenbird	1.23	0.11	1.24	0.11	1.19	0.11	1.29	0.11	1.44	0.12	1.38	0.12	0.1759	0.4426	0.1050
Connecticut Warbler	0.10	0.04	0.10	0.04	0.06	0.03	0.10	0.04	0.04	0.03	0.01	0.01	0.1970	0.5191	0.0645
Mourning Warbler	0.31	0.06	0.36	0.06	0.29	0.07	0.26	0.06	0.22	0.05	0.26	0.05	0.6583	0.3723	0.2051
Common Yellowthroat	0.25	0.05	0.27	0.06	0.30	0.08	0.23	0.06	0.30	0.07	0.34	0.08	0.5468	0.5555	0.2831
Canada Warbler	0.14	0.04	0.14	0.05	0.09	0.03	0.22	0.06	0.22	0.06	0.18	0.06	0.2816	0.0347	0.9858
Scarlet Tanager	0.14	0.04	0.10	0.03	0.20	0.05	0.12	0.04	0.08	0.03	0.07	0.03	0.0529	0.8894	0.4260
Rose-breasted Grosbeak	0.17	0.05	0.20	0.05	0.27	0.06	0.21	0.05	0.25	0.06	0.25	0.05	0.8988	0.3640	0.3137
Chipping Sparrow	0.17	0.05	0.15	0.05	0.18	0.06	0.16	0.04	0.15	0.05	0.11	0.04	0.8938	0.5343	0.9205
Song Sparrow	0.24	0.06	0.18	0.04	0.26	0.07	0.12	0.04	0.27	0.07	0.21	0.06	0.0919	0.9467	0.1213
Swamp Sparrow	0.08	0.03	0.07	0.03	0.06	0.03	0.04	0.02	0.08	0.04	0.10	0.04	0.9644	0.8033	0.2462
White-throated Sparrow	0.75	0.08	0.63	0.09	0.63	0.09	0.47	0.07	0.69	0.10	0.53	0.09	0.0030	0.2389	0.2693
Brown-headed Cowbird	0.07	0.03	0.08	0.03	0.04	0.02	0.06	0.03	0.01	0.01	0.07	0.04	0.6858	0.3116	0.1790
American Goldfinch	0.02	0.02	—	—	—	—	0.02	0.02	0.06	0.03	0.06	0.03	0.2867	0.2089	0.0379

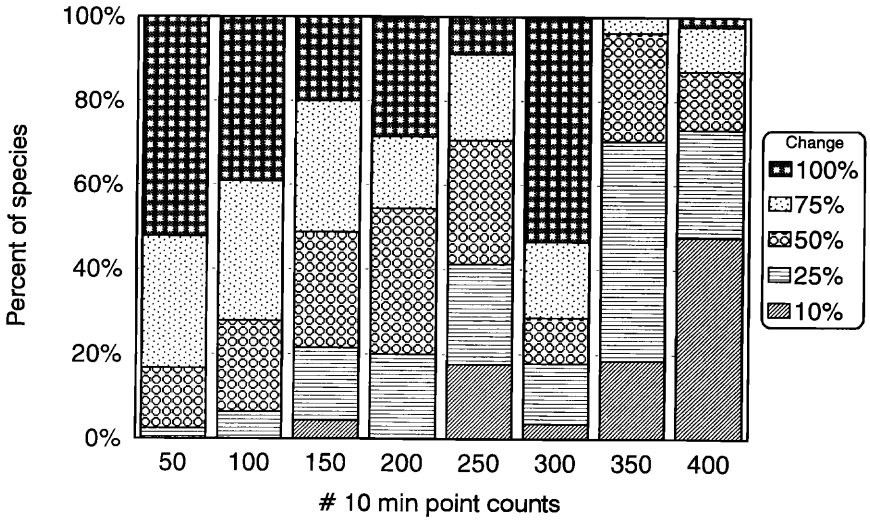

FIGURE 2. Percent of species tested where a 10–100% change in abundance could be detected if 50–400 point counts were conducted on a road in non-specific habitats (like the breeding bird survey). Percent change detectable was calculated with SOLO power analysis (BMDP Statistical Software, Inc. 1992).

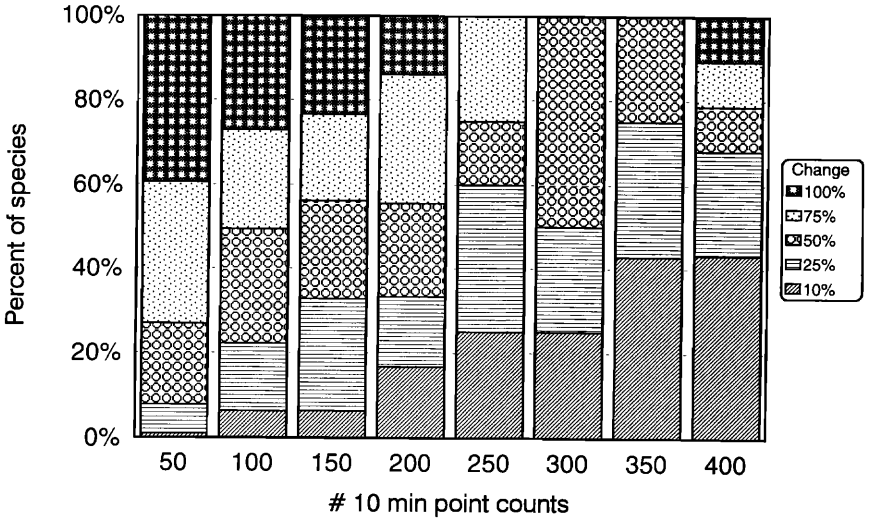

FIGURE 3. Percent of species tested where a 10–100% change in abundance could be detected if 50–400 point counts were conducted off road in specific habitats. Percent change detectable was calculated with SOLO power analysis (BMDP Statistical Software, Inc. 1992).

more commonly counted on roads included those that use roads as corridors to locate food (e.g., Common Crow and Blue Jay).

Other species observed only along the roads were associated with open wetlands (seven species in Table 1). As off-road habitat-specific counts were not done in these habitats, some differences in species composition can be explained by habitats sampled. All four species observed only on off-road counts were species that are associated with lowland conifer habitat, which was not commonly sampled with the on-road counts, even though these routes were randomly selected. Some habitats may not be sampled with roadside counts because the probability of them occurring along roads is lower. For example, as a result of the difficulty and expense of placing roads through large wetlands, spruce and tamarack bogs are not commonly traversed by roads. Similar patterns of differences in species observed were not apparent for the near and within-stand paired counts. This lack of difference was likely because habitat differences were factored out by pairing points within the same stand.

Other differences in species abundance patterns between on- and off-road counts could be attributed to the proportions of habitats that were included in each group. The percent of points within upland conifer (pine), upland mixed (conifer and deciduous), lowland mixed, and lowland deciduous habitat were similar among the count groups, but off-road counts had more points in lowland conifer types and on-road counts had more points in upland deciduous types (Fig. 4). Differences in habitats between on- and off-road counts contributed to many significant differences that were detected between species observed on and off roads. For example, the Yellow-bellied Sapsucker, Red-eyed Vireo, Ovenbird and Rose-breasted Grosbeak are all associated with upland deciduous habitats and all were more abundant on roads. In contrast, Connecticut Warbler, Golden-crowned Kinglet and Yellow-bellied Flycatcher are found in lowland conifer habitats and all were more abundant in off-road counts.

Sample size and power of statistical analyses.—The power or ability to detect a smaller difference among means was greatest for counts conducted off-road in specific habitats. For example, to detect a 25% change or less in species abundance between years for 50% of the species would require about 250 off-road counts (Fig. 2) and about 350 on-road counts (Fig. 3). The greater power with off-road habitat specific counts can be attributed to the lower variance associated with the mean of the off-road counts in comparison with those on roads. This power can be attributed to sampling in only one habitat type in the off-road counts, whereas randomly selected roadside counts often sample more than one habitat type and edges. On the basis of these results, the most cost-efficient counts would be those placed in specific habitats along roads. This conclusion is based on the assumption that more counts could be conducted per day on road than off road and whether a large number of suitable stands could be located along roads that have a closed canopy. Again, a big advantage of habitat-specific counts is that changes in bird abundance

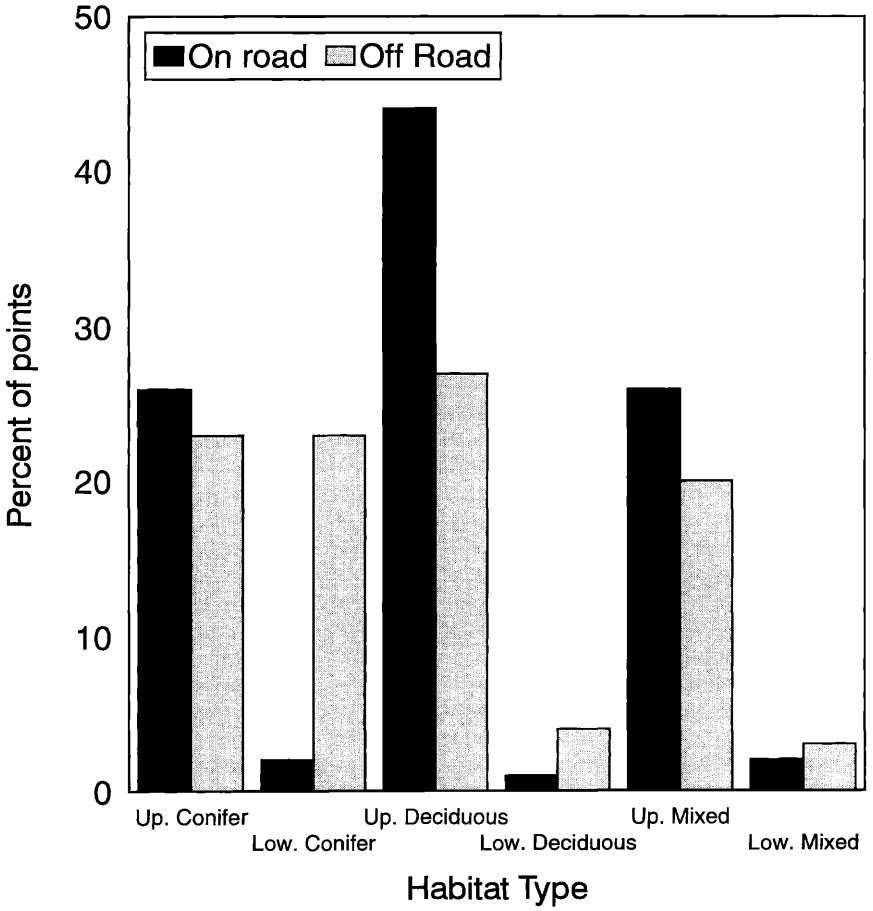

FIGURE 4. Percent of points for the on- and off-road counts that were identified within six general habitat types.

over time can be more easily related to changes in habitat that occur in the region.

General recommendations.—Our data support recommendations suggested by Ralph et al. (1993) and those in Ralph et al. (1994) that bird monitoring in National Forests should be habitat specific (see also Hanowski and Niemi 1994). We agree with the suggestion that points can be placed on roads with the restriction that points be selected randomly and placed within distinct habitat types and that roads selected for sampling have a closed canopy. Evidence provided here also agrees with recommendations that some points be placed off road in habitats not sampled with on-road counts. The suggestion that one third of the points be placed off road is probably too restrictive for this region, however. Specific

monitoring plans may be different for each Forest and may depend on types and distribution of roads, habitats sampled and objectives of the monitoring. On-road counts offer advantages over off-road counts because more counts can be completed per morning and because roads are physically easier to sample.

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