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A Comparison of Bird Detection Rates Derived from On-Road versus Off-Road Point Counts in Northern Montana¹

Richard L. Hutto, Sallie J. Hell, Jeffrey F. Kelly and Sandra M. Pletschet²

Abstract: We conducted a series of 275 paired (on- and off-road) point counts within 4 distinct vegetation cover types in northwestern Montana. Roadside counts generated a bird list that was essentially the same as the list generated from off-road counts within the same vegetation cover type. Species that were restricted to either on- or off-road counts were rare, suggesting that restricted occurrences were a consequence of small sample sizes and not a product of habitat differences surrounding on-versus off-road points. Nevertheless, there were significant differences in the mean number of individuals detected between on- and off-road points for a number of species. Some of these differences appear to be a product of habitat changes associated with the presence of roads, and those differences appear to be less pronounced on narrower roads. Therefore, we recommend that, if one wishes to extrapolate results from on- to off-road areas, care should be taken to select smaller, secondary or tertiary roads as transect routes.

Numerous private, state, and federal land management agencies are beginning to recognize the practicality of using information about the health of songbird populations as an effective tool in meeting part of their legal and ethical requirements to monitor the populations of all vertebrate species. With the desire of most agencies to develop an extensive, rather than intensive, monitoring system, and with the already-existing roadside North American Breeding Bird Survey (BBS) in place, it appears likely that many of these agencies will choose to supplement the BBS with some sort of roadside monitoring method. Before expanding our efforts to obtain roadside data, we must evaluate the possible biases associated with roadside counts. Specifically, if roadside data are to be used to monitor bird populations, we need to know: (1) if the sample is representative of off-road samples in the same habitat and (2) whether population trends of on-road birds mirror those of off-road bird populations.

While it may be difficult, if not impossible, without long-term data sets to compare trends of bird populations based on on-road versus off-road counts, it is relatively simple to test how well roadside counts sample the more broadly defined habitats through which they pass. It is, therefore, surprising that there are no published studies related to this issue (Keller and Fuller, and Ralph and others, in this volume). If on-road counts are similar to off-road counts, there is a strong chance that population trends would be similar as well. If, however, on- and off-road counts differ substantially due

to the distinct habitat conditions created by the presence of a road, those distinct conditions might also affect the population dynamics of occupants, resulting in different population trends as well.

The objective of our study was to test whether the abundances of various bird species differ significantly between on- and off-road point counts. We categorized our data by bird species, vegetation type, and road width to gain insight into possible causes of any observed differences.

Methods

We conducted 550 point counts along secondary roads within the Flathead National Forest—Big Fork and Glacier View Ranger Districts—and Glacier National Park, Montana, from May 31 to July 12, 1991 (peak breeding season). Counts were paired (275 pairs), with one on the road and the other perpendicular to and 200 m away from the road. Both on- and off-road points were located within the same vegetation cover type, and neither was within 200 m of an abrupt vegetation edge or another road. To find locations that had continuous vegetation cover of a single type (see vegetation categories below) for at least 400 m on both sides of the road, the vegetation context of a given stretch of road was determined beforehand from SPOT Image Corporation (SPOT) satellite images and from conversations with land managers. Before we conducted the actual point counts, we also confirmed that the points would be in continuous habitat by walking or driving through the site.

We conducted point counts within each of 4 vegetation cover types: recently burned forest ($n = 44$ pairs), early successional forest ($n = 34$ pairs), open forest ($n = 52$ pairs), and closed forest ($n = 145$ pairs). In the burned sites, virtually all of the trees were dead, and standing trees had not been removed since a 1988 fire. The understory was composed primarily of forbs, but some shrubs had begun resprouting. Early successional sites were regenerating from clear-cutting and were covered with shrubs, generally less than 3 m tall; occasionally, there were a few large trees present. Open forests included sites where the canopy was not continuous, either because the trees had been thinned through logging, or because a considerable number of standing trees were dead from natural causes. The understory in the open sites varied from sparsely scattered to moderately dense shrubs and saplings. The size and density of trees in the closed forest varied from large, well-spaced "old-growth" trees to smaller, more densely packed trees. The understory within the closed forest sites also varied greatly, from open to very dense shrub and sapling cover.

In association with each on-road point, we estimated the width of the road by pacing the distance from one edge of the

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graded portion to the other. The distribution of road widths was distinctly bimodal, with the majority being less than 10 m wide. Roads less than 10 m wide were classified as "narrow," and those greater than 10 m wide were classified as "wide."

Two observers used 10-minute, fixed-radius plots to record all birds detected within each of two distance categories: within 50 m, and between 50 and 100 m. Visual cues, calls, and songs were used to identify bird species. Point counts were begun about 15 minutes after sunrise and ended before the midday lull in bird activity, generally before 1030. Points were placed at 200-m intervals along roads, and observer bias was controlled by alternating the two observers between on- and off-road counts.

To compare on- and off-road bird communities, we used the Wilcoxon matched-pairs signed-ranks test on measures of overall abundance (mean number of individuals per point) and species richness (mean number of species per point). To compare detection rates of individual species, we used the Wilcoxon test on the mean number of individuals per point, and the *G*-test on frequencies of on- versus off-road detection (Sokal and Rohlf 1981). Tests were considered significant at $P < 0.05$. All analyses were conducted with SPSS-PC computer software.

Results

We detected a total of 64 species within a 50-m radius (*table 1*). Fifty-one (80 percent) of those species were detected on both on- and off-road counts. Nine were detected only on the on-road counts, and four were detected only on the off-road counts. The patterns were similar for 100-m-radius data: 68 species were detected, 59 (87 percent) on both on- and off-road counts, 9 were detected only on roads, and none were detected only off roads (*table 1*).

For either count radius, all species detected either only on-road or only off-road were rare; they were detected on 4 or fewer of the 550 point counts. For those species, the mean number of counts on which they were detected was 1.5 within a 50-m radius, and 2.0 within 100 m. In contrast, the average species was detected on 31.9 and 56.3 counts for the 50- and 100-m radius data, respectively.

The mean species richness at a given count point was significantly greater for on-road than for off-road counts (*table 2*). Most species (62-66 percent, depending on count radius and measure of abundance used) had either a greater frequency of detection, or a greater average number of detections per point, for on-road than for off-road counts (*table 1*). If we restrict analysis to the 31 species that were detected on at least 25 points (*table 1*), the frequency of detection was significantly greater on on-road counts for seven species, and no species was significantly more frequently detected on off-road counts. Similarly, the number of detections per point was significantly greater on on-road counts for nine species, whereas none had a significantly larger number of detections per point off road. These results held true regardless of the count radius used. The species that had either a significantly greater frequency of detection, or a significantly larger number of detections per point, represent a diverse cross-section in terms of their behavior and general feeding locations.

The proportion of detections that came from on-road versus off-road varied significantly among species ($G = 86.1$, $P = 0.000$ for 50-m radius data; $G = 63.3$, $P = 0.001$ for 100-m radius data). To contrast the kinds of species that were relatively more likely to be detected on roadside counts with those that were less likely to be detected, we simply tallied six species from each end of the spectrum (*table 3*). On the basis of our own field experience in northern Rocky Mountain forests, most of the species with the highest proportions of on-road detections can be safely classified as those that forage along either the forest opening or the shrubby vegetation associated with the presence of a road. In contrast, most of the species that cluster toward the lower proportion of on-road detections are forest interior species.

To determine whether the effect of roads was more pronounced in some vegetation types than in others, we tallied the total number of detections on and off roads for each bird species. We then calculated the absolute value of the on/off road difference in number of detections for each species. The averages of those differences for each of the four vegetation cover types vary significantly among cover types (*table 4*). For data from both count radii, the greatest average magnitudes of difference between the numbers of on- and off-road detections occurred in the forested cover types.

We used data from the heavily forested vegetation cover type to assess the effect of road width on detection rates (the other cover types had only a few wide-road samples). The mean number of birds detected per point on and off narrow roads did not differ significantly ($t = 0.64$, NS for 50-m-radius data; $t = 0.35$, NS for 100-m-radius data), while the mean number of birds detected per point on and off wide roads did ($t = 4.29$, $P < 0.001$ for 50-m-radius data; $t = 4.57$, $P < 0.001$ for 100-m-radius data); there were significantly more birds detected on than off wide roads (*fig. 1*).

The pronounced effect of road width suggested that the on- vs. off-road difference in the number of detections for most species might disappear if we restricted our analysis to narrow roads only. Of the 11 species whose average number of detections differed significantly between on- and off-road counts for at least 1 of the 2 count radii (*table 1*), 5 (Ruby-crowned Kinglet (*Regulus calendula*), American Robin (*Turdus migratorius*), Warbling Vireo (*Vireo gilvus*), Yellow-rumped Warbler (*Dendroica coronata*), and MacGillivray's Warbler (*Opornis tolmiei*)) still revealed a significant difference in the number of individuals detected per point after restricting the analysis to data from narrow roads only. Interestingly, by so restricting the analysis, the on- versus off-road difference in mean number of detections changed from insignificant to significant for one species, Varied Thrush (*Ixoreus naevius*).

Discussion

Roadside counts appear to be adequate for the generation of complete bird lists. Species that were restricted to either on- or off-road counts were rare, suggesting that restricted occurrences were a product of small sample sizes and not a product of habitat differences between on- and off-road points. Nevertheless, a number of the more common species were significantly more likely to be detected on on-road

Table 1--The number of point counts on which a given species was detected, and the mean number of detections per point (x 100) for on-road (n = 275) and off-road (n = 275) counts within each of two count radii.

Species	Frequency of occurrence				Mean number per point (x100)			
	50-m radius		100-m radius		50-m radius		100-m radius	
	On road	Off road	On road	Off road	On road	Off road	On road	Off road
Sharp-shinned Hawk <i>Accipiter striatus</i>	0	1	1	1	0.00	0.36	0.36	0.36
Red-tailed Hawk <i>Buteo jamaicensis</i>	0	0	3	0	0.00	0.00	1.09	0.00
American Kestrel <i>Falco sparverius</i>	2	1	5	2	0.73	0.36	1.82	0.73
Merlin <i>Falco columbarius</i>	0	0	1	0	0.00	0.00	0.36	0.00
Ruffed Grouse <i>Bonasa umbellus</i>	0	1	6	11	0.00	0.36	2.18	4.00
Common Snipe <i>Gallinago gallinago</i>	1	1	2	3	0.36	0.36	0.73	1.45
Calliope Hummingbird <i>Stellula calliope</i>	20	10	20	10	8.36	4.00 ^d	8.36	4.00 ^d
Rufous Hummingbird <i>Selasphorus rufus</i>	15	7	15	7	6.18	2.55	6.18	2.55
Red-naped Sapsucker <i>Sphyrapicus nuchalis</i>	16	15	30	27	6.55	6.55	11.64	12.00
Downy Woodpecker <i>Picoides pubescens</i>	2	0	2	0	0.73	0.00	0.73	0.00
Hairy Woodpecker <i>Picoides villosus</i>	4	5	8	16	1.82	2.18	3.64	6.55
Three-toed Woodpecker <i>Picoides tridactylus</i>	8	3	10	5	4.00	1.82	4.73	2.55
Black-backed Woodpecker <i>Picoides arcticus</i>	3	0	4	0	1.45	0.00	1.82	0.00
Northern Flicker <i>Colaptes auratus</i>	7	10	17	19	2.55	4.73	7.27	9.45
Pileated Woodpecker <i>Dryocopus pileatus</i>	0	1	5	6	0.00	0.36	1.82	2.18
Olive-sided Flycatcher <i>Contopus borealis</i>	5	1	24	22	2.18	0.36	9.09	8.36
Western Wood-Pewee <i>Contopus sordidulus</i>	2	5	10	13	0.73	1.82	5.09	5.45
Dusky and Hammond's Flycatchers <i>Empidonax</i> sp. ^a	32	17 ^c	36	24	11.64	6.18 ^d	13.09	8.73
Eastern Kingbird <i>Tyrannus tyrannus</i>	1	0	1	0	0.36	0.00	0.36	0.00
Tree Swallow <i>Tachycineta bicolor</i>	9	12	13	16	6.18	8.36	9.09	12.00
Gray Jay <i>Perisoreus canadensis</i>	18	12	40	36	13.09	7.27	24.73	18.55
Steller's Jay <i>Cyanocitta stelleri</i>	1	1	5	2	0.36	0.36	1.82	0.73
Clark's Nutcracker <i>Nucifraga columbiana</i>	0	0	1	0	0.00	0.00	0.73	0.00
Common Raven <i>Corvus corax</i>	3	3	24	21	1.45	1.09	10.18	8.00
Black-capped and Mountain Chickadees <i>Parus</i> sp. ^b	52	54	92	91	27.27	30.55	46.91	47.64
Boreal Chickadee <i>Parus hudsonicus</i>	2	0	2	0	2.18	0.00	2.18	0.00
Chestnut-backed Chickadee <i>Parus rufescens</i>	1	2	1	2	0.73	1.09	0.73	1.09
Red-breasted Nuthatch <i>Sitta canadensis</i>	59	50	132	136	25.82	20.73	58.18	62.91
Brown Creeper <i>Certhia americana</i>	7	12	8	13	2.55	4.73	2.91	5.09
House Wren <i>Troglodytes aedon</i>	1	0	1	0	0.36	0.00	0.36	0.00
Winter Wren <i>Troglodytes troglodytes</i>	3	10	4	12	1.09	3.64	1.82	4.36
Golden-crowned Kinglet <i>Regulus satrapa</i>	19	26	20	26	9.09	12.36	9.82	12.73

continued

Table 1-continued

Species	Frequency of occurrence				Mean number per point (x100)			
	50-m radius		100-m radius		50-m radius		100-m radius	
	On road	Off road	On road	Off road	On road	Off road	On road	Off road
Ruby-crowned Kinglet <i>Regulus calendula</i>	33	24	76	62	16.73	10.55	36.73	27.64 ^d
Mountain Bluebird <i>Sialia currucoides</i>	4	3	12	8	4.36	1.82	8.73	5.82
Townsend's Solitaire <i>Myadestes townsendi</i>	6	3	19	10	3.27	1.09	8.73	4.36
Swainson's Thrush <i>Catharus ustulatus</i>	97	85	166	141 ^c	41.09	38.55	92.00	86.91
American Robin <i>Turdus migratorius</i>	47	25 ^c	91	82	21.82	11.64 ^d	50.18	40.73
Varied Thrush <i>Ixoreus naevius</i>	9	4	30	22	3.64	1.45	12.73	9.45
Cedar Waxwing <i>Bombycilla cedrorum</i>	1	0	1	1	1.09	0.00	1.09	0.73
European Starling <i>Sturnus vulgaris</i>	0	1	2	1	0.00	1.09	1.82	1.09
Solitary Vireo <i>Vireo solitarius</i>	10	16	32	37	3.64	5.82	11.64	13.45
Warbling Vireo <i>Vireo gilvus</i>	40	19 ^c	62	35 ^c	17.09	7.64 ^d	26.55	15.64 ^d
Red-eyed Vireo <i>Vireo olivaceus</i>	2	2	2	4	1.09	0.73	1.09	1.45
Orange-crowned Warbler <i>Vermivora celata</i>	31	27	44	50	12.36	13.45	21.82	26.18
Yellow-rumped Warbler <i>Dendroica coronata</i>	75	62	116	84 ^c	33.45	25.09 ^d	56.73	39.27 ^d
Townsend's Warbler <i>Dendroica townsendi</i>	70	81	102	112	31.27	35.64	56.00	60.36
American Redstart <i>Setophaga ruticilla</i>	7	1	11	3	2.55	0.73	4.00	1.45
Northern Waterthrush <i>Seiurus noveboracensis</i>	8	5	20	12	2.91	2.18	8.00	5.09
MacGillivray's Warbler <i>Oporornis tolmiei</i>	91	65 ^c	122	96 ^c	41.45	28.00 ^d	61.09	42.18 ^d
Common Yellowthroat <i>Geothlypis trichas</i>	8	5	14	11	3.27	2.18	6.55	4.36
Wilson's Warbler <i>Wilsonia pusilla</i>	30	15 ^c	37	21 ^c	14.91	6.18 ^d	20.00	10.18 ^d
Western Tanager <i>Piranga ludoviciana</i>	27	34	54	65	12.36	13.45	23.64	26.55
Black-headed Grosbeak <i>Pheucticus melanocephalus</i>	3	4	10	10	1.09	1.45	4.00	4.73
Lazuli Bunting <i>Passerina amoena</i>	2	1	4	1	1.09	0.36	1.82	0.73
Chipping Sparrow <i>Spizella passerina</i>	64	36 ^c	104	87	38.55	18.91 ^d	59.64	44.00 ^d
Fox Sparrow <i>Passerella iliaca</i>	8	4	20	13	3.27	1.45	9.45	5.82
Song Sparrow <i>Melospiza melodia</i>	3	0	3	0	1.09	0.00	1.45	0.00
Lincoln's Sparrow <i>Melospiza lincolnii</i>	5	6	16	16	2.18	4.00	6.91	9.09
White-crowned Sparrow <i>Zonotrichia leucophrys</i>	4	2	9	5	2.18	1.45	4.73	2.55
Dark-eyed Junco <i>Junco hyemalis</i>	154	129 ^c	199	179	96.00	71.27 ^d	146.18	114.55 ^d
Red-winged Blackbird <i>Agelaius phoeniceus</i>	1	0	4	4	0.36	0.00	2.18	1.82
Brown-headed Cowbird <i>Molothrus ater</i>	3	1	3	4	1.82	0.36	1.82	1.45
Pine Grosbeak <i>Pinicola enucleator</i>	1	0	2	3	1.09	0.00	1.45	1.45
Cassin's Finch <i>Carpodacus cassinii</i>	3	2	6	5	1.09	1.45	2.18	2.55

continued

Table 1--continued

Species	Frequency of occurrence				Mean number per point (x100)			
	50-m radius		100-m radius		50-m radius		100-m radius	
	On road	Off road	On road	Off road	On road	Off road	On road	Off road
Red Crossbill <i>Loxia curvirostra</i>	0	0	1	1	0.00	0.00	0.73	0.36
White-winged Crossbill <i>Loxia leucoptera</i>	4	3	6	5	1.82	6.55	4.73	7.27
Pine Siskin <i>Carduelis pinus</i>	55	42	91	73	40.73	29.09	69.09	51.64 ^d
Evening Grosbeak <i>Coccothraustes vespertinus</i>	5	1	5	4	4.36	0.73	4.36	1.82

^aVocalizations of Dusky and Hammond's Flycatchers were difficult to distinguish, so data from the two species were combined.

^bVocalizations of Black-capped and Mountain Chickadees were difficult to distinguish, so data from these two species were combined.

^cOn- and off-road counts differ significantly (*G*-test, *P* < 0.05).

^dOn- and off-road detection rates differ significantly (Wilcoxon matched-pairs signed-ranks test, *P* < 0.05).

Counts than on off-road counts. The possible explanations fall into one of two categories: (1) habitat changes (because of vegetation changes or the presence of a road per se) cause differences in either actual population densities or in the detection probability (behavior) of on-road versus off-road birds; or (2) actual bird densities or behaviors do not differ, but there is a visual, auditory, or area-estimate bias associated with on-road and off-road counts. We can gain insight into the probable explanation by examining results from analyses that were categorized by bird species, habitat, and road width.

Because the bird species whose detection rates differed significantly represent a varied group in terms of their foraging locations and behaviors, it seems unlikely that a single form of habitat influence can be used to explain those differences. Nonetheless, most of the species that differed are generally associated with habitat conditions that are similar to those created by the presence of a road. For example, considering the species whose detection rates differed significantly between on- and off-road counts (table 1), it is easy to see how an increase in roadside shrub vegetation would be attractive to, and lead to higher counts of, Dusky Flycatcher (*Empidonax oberholseri*), Warbling Vireo, MacGillivray's warbler, and Wilson's Warbler (*Wilsonia pusilla*), because they each feed or nest, or both, in shrubby vegetation. In addition, the Calliope Hummingbird (*Stellula calliope*), American Robin, Chipping Sparrow (*Spizella passerina*), Dark-eyed Junco (*Junco hyemalis*), and Pine Siskin (*Carduelis pinus*) each feed primarily from the grass and forb layer, which is especially well developed along side roads. Finally, the Hammond's Flycatcher (*Empidonax hammondi*), Yellow-rumped Warbler and Ruby-crowned Kinglet occur

Table 2—The mean number of species (± s.d.) detected per point on on-road and off-road counts for each of two count radii.

Count radius	Point Location		<i>t</i>	<i>P</i>
	On road	Off road		
50 m	4.39 ± 2.1	3.53 ± 1.9	5.16	0.000
100 m	7.44 ± 2.5	6.53 ± 2.5	4.27	0.000

commonly along natural forest edges and openings, and roadside edges may be used similarly. The argument that habitat changes associated with the presence of roads are causing the observed differences gains additional credence if we examine the list of species that had the relatively fewest detections on roadside counts (table 3). Most can be clearly recognized as forest interior specialists.

The large variety in kinds of species whose detection rates differ significantly between on- and off-road counts is also consistent with the idea that those differences are a product of some kind of sampling bias associated with either on- or off-road counts. For example, if we overestimated the area surveyed for on-road relative to off-road counts, we would have expected a diverse group of species to be affected. However, because the magnitude of any area-estimate bias would be expected to differ between data based on 50-m and 100-m radii, we should also have expected the number of significant on- versus off-road differences in detection rates

Table 3—Six species with the relatively greatest and relatively least number of detections (expressed as a percentage of the total number of detections) on 50-m radius on-road (versus off-road) counts. The pool of species was restricted to those with at least 25 detections.

Species	On road <i>n</i>	On road percent
Wilson's Warbler	58	70.7
Warbling Vireo	68	69.1
Calliope Hummingbird	34	67.6
Chipping Sparrow	158	67.1
Dusky and Hammond's Flycatchers	49	65.3
American Robin	92	65.2
Orange-crowned Warbler	71	47.9
Western Tanager	71	47.9
Townsend's Warbler	184	46.7
Tree Swallow	40	42.5
Golden-crowned Kinglet	59	42.4
Solitary Vireo	26	38.5
All 64 species	2948	56.4

Table 4--Means (\pm s.d.) from absolute values of the differences between the on-road and off-road number of detections in each of four vegetation cover types. Data are from all species combined.

Vegetation type	50-m radius ^a	100-m radius ^b
Burned forest	2.60 \pm 3.1	3.91 \pm 4.3
Early successional	2.24 \pm 3.1	2.87 \pm 2.7
Open forest	3.93 \pm 5.1	4.48 \pm 5.0
Closed forest	5.18 \pm 7.3	7.22 \pm 9.3

^a Means vary significantly among vegetation types (ANOVA; $F = 3.17$, $P = 0.026$).

^b Means vary significantly among vegetation types (ANOVA; $F = 4.36$, $P = 0.005$).

to change from one count radius to the next. In fact, the same number of species had significantly different detection rates under each sampling radius (nine species, based on mean numbers detected per point (table 1)). Thus, in the absence of other information, an evaluation of the identity of species affected would leave us with the impression that multiple habitat factors best account for the differences in detection rates between on- and off-road count points.

How can a breakdown by vegetation cover types help us interpret our results? If species are responding to the presence of an opening or to an increase in shrub cover, we might expect the on/off-road difference in the number of detections to be greater in closed forests because off-road points are surrounded by little early successional vegetation relative to the on-road points. This was indeed the case. The greatest average difference between on-road and off-road counts occurred in closed forest, followed by open forest, and then the early successional cover types (table 4). Nevertheless, the results are consistent with an area-estimate bias as well.

Finally, the observation that there was less difference between on- and off-road counts on narrow than on wide roads (fig. 1) is also consistent with either interpretation. The wider roads that we surveyed had associated with them an apron of grass along both edges, significant shrub cover and, of course, a wide forest opening. Those kinds of habitat changes associated with roads may explain the relatively large differences between on- and off-road counts. If this were the case, however, we would have expected the off-road counts to be similar for narrow and wide roads, and the on-road counts to be larger for wide roads. Instead, we found that the mean number of birds per off-road point was less on wide roads than on narrow roads, while the mean numbers of birds per point on roadside counts were nearly the same for wide and narrow roads (fig. 1). The difference in off-road detection rates between wide and narrow roads is probably a reflection of the fact that, even though we restricted analysis to the "closed forest" cover type, the paired points from wider roads were situated in predominantly lodgepole pine (*Pinus contorta*) forest, a notoriously bird-poor habitat type, while most of the paired points from narrower roads were situated in mixed conifer stands. Thus, the "baseline" detection rates for our wide road samples may be lower than for the narrow road samples, but the results are still consistent with the conjecture that habitat differences between on- and off-road points were greater in the areas with wide roads.

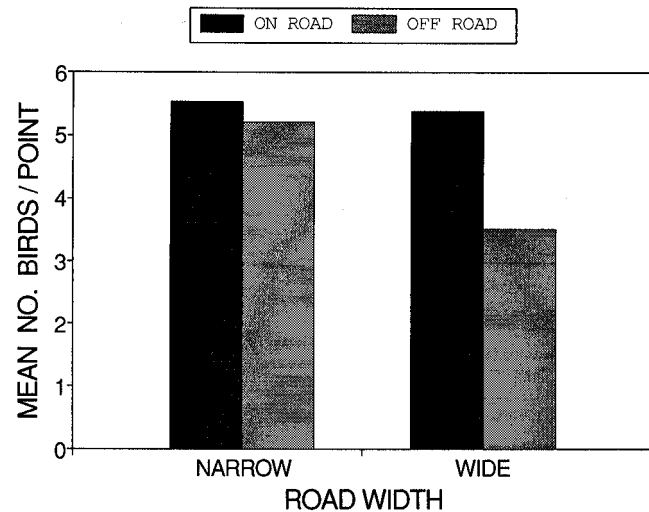


Figure 1--The mean number of birds detected per point within 50 m on on- and off-road counts for each of two road widths.

Alternatively, because it is easy to underestimate distances in open areas, the more open conditions associated with wide roads may have resulted in the inclusion of a greater number of birds that were actually beyond the formal cutoff radius than was true for narrow roads.

In conclusion, consideration of information on species identity, vegetation cover type, and road width suggests that vegetation change associated with the presence of roads is an important factor contributing to a difference between on- and off-road count data. In addition, the particular kind of roadside vegetation change that affects the count data (whether it is the presence of an opening, a grassy area, or an increase in shrub cover) probably differs among species, and may not affect some species at all. In short, changes in a variety of habitat elements probably caused the patterns we observed, which is merely a reflection of the fact that every species is biologically unique. Thus, one must understand enough about the biology of each target species to make a decision about whether the exclusive use of roadside counts is appropriate for a particular study.

Because some species were almost certainly responding to the changed habitat conditions brought about by the presence of a road, we recommend that studies of habitat associations treat roadside conditions as unique "habitats" in and of themselves. This should be especially true for studies involving wide roads or heavily forested habitats, or both, because roadside effects appear to be most pronounced in those situations. Thus, counts restricted to primary roads will probably not assure a representative coverage of habitat types because, in effect, such counts do not include the off-road contexts of the habitat types through which they pass. By the same token, studies designed to use only off-road points would be missing samples from those special habitat conditions created by the presence of roads.

If the goal of one's study is to monitor bird population trends over a broad region, we recommend combining on- with off-road counts to avoid the possible bias of using either

exclusively. Our results also suggest, however, that off-road counts are more-or-less equivalent to on-road counts when the road is a small secondary or tertiary road. Therefore, if roads are to be used, perhaps the simplest design would call for use of smaller roads that have the same vegetation cover types within 100 m to either side and that appear to have resulted in little, if any, change in the

vegetative conditions immediately adjacent to the road. Sample points can then be stratified by the habitat type through which the road passes.

Unfortunately, the issue of whether or not to use roadside counts is nearly a moot point on much of our public land. It was difficult to find any locations, especially in bottomlands, that were more than 200 m from an existing road (*fig. 2*). By



Figure 2--A scene typical of the roaded landscape found on forested public lands throughout much of the northern Rocky Mountains (USDA Forest Service photo 611030 1186-94).

default, we will be forced to sample bird populations over much of the public landscape in what are basically roadside environments. In those parts of the country where we are fortunate enough to still have sizable blocks of largely roadless areas, there should be a premium on establishing monitoring programs so that we will be able to better understand the effects of roads on not only count data themselves, but on trends of populations situated near versus far from roads.

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