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Research Paper

Off-road sampling reveals a different grassland bird community than roadside sampling: implications for survey design and estimates to guide conservation

Troy I. Wellicome [1], *Kevin J. Kardynal* [1], *Renee J. Franken* [1,2] and *Cameron S. Gillies* [2]

[1]Canadian Wildlife Service, Environment Canada, Edmonton, AB, Canada, [2]Tierra Environmental Consulting, Windermere, BC, Canada

ABSTRACT. Grassland bird species continue to decline steeply across North America. Road-based surveys such as the North American Breeding Bird Survey (BBS) are often used to estimate trends and population sizes and to build species distribution models for grassland birds, although roadside survey counts may introduce bias in estimates because of differences in habitats along roadsides and in off-road surveys. We tested for differences in land cover composition and in the avian community on 21 roadside-based survey routes and in an equal number of adjacent off-road walking routes in the grasslands of southern Alberta, Canada. Off-road routes (n = 225 point counts) had more native grassland and short shrubs and less fallow land and road area than the roadside routes (n = 225 point counts). Consequently, 17 of the 39 bird species differed between the two route types in frequency of occurrence and relative abundance, measured using an indicator species analysis. Six species, including five obligate grassland species, were more prevalent at off-road sites; they included four species listed under the Canadian federal Species At Risk Act or listed by the Committee on the Status of Endangered Wildlife in Canada: Sprague's Pipit (*Anthus spragueii*), Baird's Sparrow (*Ammodramus bairdii*), the Chestnut-collared Longspur (*Calcarius ornatus*), and McCown's Longspur (*Rhynchophanes mccownii*). The six species were as much as four times more abundant on off-road sites. Species more prevalent along roadside routes included common species and those typical of farmland and other human-modified habitats, e.g., the European Starling (*Sturnus vulgaris*), the Black-billed Magpie (*Pica hudsonia*), and the House Sparrow (*Passer domesticus*). Differences in avian community composition between roadside and off-road surveys suggest that the use of BBS data when generating population estimates or distribution models may overestimate certain common species and underestimate others of conservation concern. Our results highlight the need to develop appropriate corrections for bias in estimates derived from roadside sampling, and the need to design surveys that sample bird communities across a more representative cross-section of the landscape, both near and far from roads.

L'échantillonnage hors route révèle une communauté d'oiseaux de prairie différente de celle issue de l'échantillonnage le long des routes : répercussions sur la conception des relevés et les estimations pour orienter la conservation

RÉSUMÉ. Le déclin prononcé des espèces d'oiseaux de prairie se poursuit en Amérique du Nord. Les relevés le long des routes, comme le Relevé des oiseaux nicheurs (BBS) en Amérique du Nord, sont souvent utilisés pour estimer les tendances et la taille des populations, ainsi que pour élaborer des modèles de répartition d'espèces de prairie, même si les dénombrements le long des routes peuvent introduire des biais relatifs aux estimations étant donné que les milieux le long des routes sont différents de ceux hors route. Nous avons examiné s'il y avait des différences dans l'occupation du sol et les communautés aviaires pour 21 routes en bordure desquelles se font des relevés et pour 21 trajets hors route adjacents dans les prairies du sud de l'Alberta, Canada. Les relevés hors route (n = 225 points d'écoute) comprenaient plus de prairies naturelles et d'arbustes bas, et moins de friches et de surface routière que les relevés le long des routes (n = 225 points d'écoute). Par conséquent, au moyen d'une analyse d'espèces indicatrices, nous avons trouvé que la fréquence d'occurrence et l'abondance relative de 17 des 39 espèces d'oiseaux différaient entre les deux types de relevés. Six espèces, y compris cinq espèces de prairie strictes, étaient plus abondantes dans les sites hors route; parmi ces espèces, quatre sont inscrites en vertu de la Loi sur les espèces en péril du Canada ou désignées par le Comité sur la situation des espèces en péril au Canada : le Pipit de Sprague (*Anthus spragueii*), le Bruant de Baird (*Ammodramus bairdii*), le Plectrophane à ventre noir (*Calcarius ornatus*) et le Plectrophane de McCown (*Rhynchophanes mccownii*). Les six espèces étaient jusqu'à quatre fois plus abondantes dans les sites hors route. Les espèces plus courantes le long des routes comprenaient l'Étourneau sansonnet (*Sturnus vulgaris*), la Pie d'Amérique (*Pica hudsonia*) et le Moineau domestique (*Passer domesticus*). Les différences observées dans la

Address of Correspondent: Troy I. Wellicome, Canadian Wildlife Service, Environment Canada, 9250 49th Street NW, Edmonton, AB T6B 1K5, Canada, troy.wellicome@ec.gc.ca

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composition des communautés aviaires entre les relevés le long des routes et hors route laissent croire que l'utilisation des données du BBS pour générer des estimations de population ou des modèles de répartition surestime peut-être certaines espèces communes et sous-estiment possiblement des espèces dont la conservation est préoccupante. Nos résultats soulignent le besoin d'élaborer des correctifs appropriés pour les biais relatifs aux estimations générées à partir de l'échantillonnage le long des routes, et le besoin de concevoir des relevés qui mesurent les communautés aviaires dans un échantillon plus représentatif du paysage, tant près que loin des routes.

Key Words: *agriculture; grassland birds; human-modified habitats; North American Breeding Bird Survey; roadside bias; species distribution models*

INTRODUCTION

Across North America, grassland birds continue to undergo major population declines as their native habitat is degraded through conversion to cropland, intensification of agricultural practices, and fragmentation of the remaining native habitat because of increased industrialization, e.g., increased oil and gas infrastructure and road construction (Samson and Knopf 1994, Peterjohn and Sauer 1999, Askins et al. 2007). To help prioritize conservation actions, the Partners in Flight (PIF) North American Landbird Conservation Plan identified a watch list of landbird species (Rich et al. 2004) whose populations face the greatest threat of future decline. Of the species that made the PIF priority list because of declining populations or high future threats, 40% occur in the Prairie Avifaunal Biome (Rich et al. 2004). Having accurate empirical data is important for the effectiveness and efficiency of programs such as PIF, which endeavor to conserve grassland birds, and for those who estimate species' trends.

The Breeding Bird Survey (BBS, Sauer et al. 2005) is the largest broad-scale source of bird occurrence and abundance data in North America; it was designed primarily to generate indices of long-term population trends over large geographic areas (Robbins et al. 1989, Boren et al. 1999, Coppedge et al. 2001, Sauer et al. 2003). These count data are increasingly used to achieve other goals, such as generating continental population estimates (e.g., Rich et al. 2004, Thogmartin et al. 2006) and building species distribution models (e.g., Scott et al. 2002, Thogmartin et al. 2004, Guisan and Thuiller 2005, Niemuth et al. 2005, Murray et al. 2008). When combined with Geographic Information Systems (GIS) and remote sensing data, spatial distribution models can predict species occurrences and can estimate species' distributions over large areas (Scott et al. 2002, McCarthy et al. 2012). However, such spatial extrapolations most often assume that sampling is representative of the habitat and bird community across the broader landscape. Violations of this assumption could severely weaken the model's predictions and the conservation programs that they inform (Brotons et al. 2004, Sauer et al. 2005, Veech 2006, Niemuth et al. 2007). Roadside bias has previously been observed in grassland birds (e.g., Hutto et al. 1995, Davis and Duncan 1999, Sutter et al. 2000) and has led to overly negative species trends in simulated models for some forest bird species (e.g., Harris and Haskell 2007) and reduced performance in predictive models for plant species distribution (Kadmon et al. 2004, Syfert et al. 2013).

The BBS survey method provides the advantages of temporal and spatial continuity of data, sometimes > 40 years of data from the same routes, broad geographic coverage, and high survey efficiency (Keller and Scallan 1999). However, the value of BBS data for modeling species occurrence and abundance across the landscape has been questioned, in part because sampling is focused on roadsides, where habitats may be greatly impacted by anthropogenic influences (Bart et al. 1995, Keller and Scallan 1999). Bird distribution and abundance may be affected by roads through avoidance, increased mortality from vehicles, decreased mating success, increased nest predation, and habitat changes associated with roads (Lima and Valone 1991, Forman and Alexander 1998, Spellerberg 1998, Forman et al. 2002, Fletcher and Koford 2003, Benítez-López et al. 2010). Such effects may exist several hundred meters or even several kilometers from roads (Benítez-López et al. 2010), perhaps depending on which of the above mechanisms is operating (e.g., Koper et al. 2009, McCarthy et al. 2012). Restricting surveys to roadsides may limit the representativeness of BBS data if habitat composition differs away from roads. Such data may result in skewed abundance, distribution, and community composition data (Thogmartin et al. 2006, Betts et al. 2007, Niemuth et al. 2007, McCarthy et al. 2012), potentially reducing the reliability of associated population and trend estimates and distribution models that are developed to guide conservation-related programs (Bart et al. 1995, 2004, Hutto et al. 1995, Francis et al. 2005, Sauer et al. 2005). Therefore, quantifying and accounting for potential sources of bias from using roadside BBS data is one of the greatest priorities for expanding the utility of this valuable continental survey (Francis et al. 2005, Sauer et al. 2005, Betts et al. 2007, McCarthy et al. 2012).

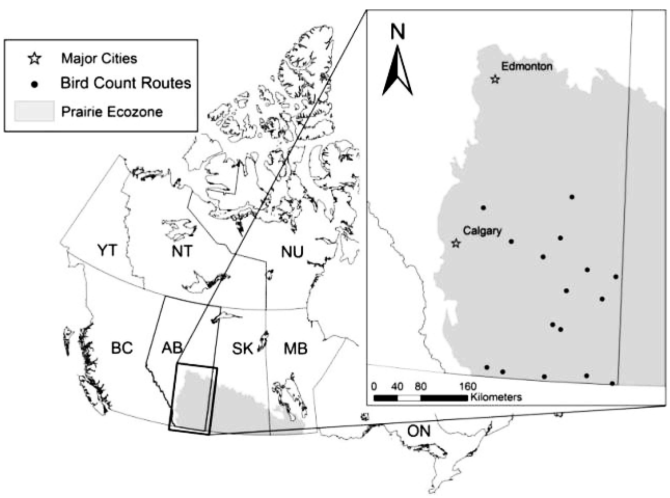
To examine the hypothesis that community composition and abundance of birds differs between roadside and off-road surveys, we conducted 21 BBS-style roadside surveys, each with an adjacent off-road survey (225 point counts in each survey type). Although differences in bird communities on roadside and off-road surveys have previously been assessed (Hanowski and Niemi 1995, Keller and Fuller 1995, Rotenberry and Knick 1995, Sutter et al. 2000), we used community composition metrics, relative abundance, and frequency of occurrence of obligate and facultative grassland birds, along with proportions of habitat types, to determine if and how bird communities differ between route types. We predicted that bird communities associated with off-road routes would consist of more obligate grassland species, based on the classification in Vikery et al. 1999, or in Poole 2005 for species not classified by Vickery et al., because of higher amounts of native habitat, whereas roadside routes would have more facultative grassland bird species and those that prefer human-modified habitats.

METHODS

Study area

We conducted this study in the southern portion of the Prairie Ecozone of southern Alberta, Canada (Fig. 1). This area is characterized by semiarid conditions (mean annual precipitation of 250 to 300 mm), mainly Brown Chernozemic and Solonetzic soils, and flat to undulating topography, with badlands occurring in isolated areas (Wiken et al. 1997). Approximately 30% of the ecozone is native prairie, excluding aspen parkland and cypress upland ecoregions, with the remaining area having been converted to cropland, tame, i.e., introduced, grasses and forbs, or rural/urban development (Gauthier and Wiken 2003). Dominant vegetation in native prairie includes grasses, e.g., speargrass (*Hesperostipa* spp.), prairie Junegrass (*Koeleria macrantha*), blue grama (*Bouteloua gracilis*), and wheatgrass (*Elymus* spp.); short shrubs such as western snowberry (*Symphoricarpos occidentalis*), rose (*Rosa* spp.), and silver sagebrush (*Artemisia cana*); tall shrubs, e.g., wolf-willow (*Elaeagnus commutata*); and tree species, e.g., aspen (*Populus* spp.) on mesic, shaded sites, e.g., coulees and river valleys. Cattle ranching is the most common use of native grassland habitats in this ecozone; cereal grains, including irrigation farming, and hay production, e.g., crested wheatgrass (*Agropyron cristatum*) and alfalfa (*Medicago sativa*) dominate the use of non-native agricultural land.

Fig. 1. Locations of point count surveys used for assessing differences in bird communities on roadside and off-road survey routes within the Prairie Ecozone (shaded area) of southern Alberta, Canada.



Bird surveys

We initially assessed candidate landscapes in which surveys were to be performed in the study area based on percent cover of the most prevalent habitat types, e.g., native grass or cultivated, within each township (9.7 km x 9.7 km). We selected townships across a wide gradient of percent cover of native grass. We chose 21 roadside routes (225 point counts), and created one off-road route adjacent to each (21 off-road routes with 225 off-road total point counts). Eight of the roadside routes were previously established for BBS surveys, and we added 13 more routes to include the broadest range of habitat type proportions available in the study landscape, because the BBS routes were typically found in more-developed landscapes with less native grassland. We randomly selected the starting point of each new roadside route within each identified township.

We conducted roadside surveys using the same methodology as the BBS (Bystrack 1981), in which observers drove the 800 m between point-count stations along asphalt, gravel, and dirt roads. An experienced observer recorded all individual birds by species seen or heard within 400 m during the 3-minute sampling period at each point count. Observers walked between stations on the off-road routes, which were paired spatially and temporally with the roadside routes and had a mean of 11 stops per route (range, 3-15), spaced 800 m apart. Off-road routes began at the sixth point count of the road route or the point count closest to the sixth for which we obtained permission for land access. The first stop of an off-road route was at least 800 m from the nearest roadside point count, to avoid double-counting birds on multiple point counts. Off-road routes typically ran perpendicular to the road for five stops, then paralleled the road for two stops, and then returned toward the road for another four stops. However, the exact direction and number of point counts on each off-road route depended on access provided by landowners. To provide a sample of habitats available on the landscape adjacent to the roadside survey route, off-road routes did not avoid other roads, trails, or particular habitat types.

All survey routes started 30 minutes before sunrise on days with wind < 20 km/hr and no precipitation, and were completed within four hours after sunrise. Surveys were conducted between 25 May and 7 July 2002. We randomly selected pairs of survey routes for sampling throughout the season to remove the potential effect of seasonality on bird detectability, e.g., territory defense behaviors, in different landscapes. Surveys of paired off-road and roadside routes usually occurred on the same day, but were always surveyed within two days of each other. Observers alternated between the type of route they surveyed, to avoid confounding treatment and observer effects.

Land cover surveys

Percent cover of various land cover types was estimated visually within a 400 m radius of the point-count station. Measured habitat variables included native grass (native species); tame grass (non-native grass species, typically used for livestock grazing); hay (non-native grass species used for livestock feed); annual crop (cultivated, seeded land); fallow (cultivated, unseeded land); water (ephemeral wetlands, livestock watering holes); development (e.g., farmstead and oil and gas infrastructure); trees; short shrubs (≤ 0.5 m in height); tall shrubs (> 0.5 m); silver sagebrush, other (e.g., badlands, sand); and roads, both gravel and asphalt. Observers were trained together to estimate land cover composition to reduce potential differences between observers. Separate from the visual estimates of percent cover, the area of road within each point-count radius was calculated, based on standard road clearance widths (30 m) in Alberta, including the road verges from the road edge to fence line on either side of the road, using a GIS. Estimates of land cover composition were made at point-count stations the day prior to bird surveys on roadside routes, and on the same day as point counts on off-road routes.

STATISTICAL ANALYSES

Land cover data

We tested for differences in land cover composition between roadside and off-road points using the proportion of habitat types estimated within a 400 m radius of each point count. Each land cover variable was tested individually to determine differences between off-road and roadside routes using Welch's *t*-test for data with unequal variance in program R version 2.15.2 (R Development

Core Team 2012). Results were considered significant at $P < 0.05$ (Table 1).

Table 1. Mean and standard deviation (SD) of habitat variables measured on roadside (n = 225) and off-road (n = 225) point counts in the Prairie Ecozone of southern Alberta, Canada.

	Roadside		Off-road	
Variable	Mean (%)	SD	Mean (%)	SD
Water	0.0089	0.0369	0.0044	0.0321
Trees	0.0019	0.0162	0.0026	0.0195
Short shrub*	0.0025	0.0201	0.0151	0.0580
Tall shrub	0.0017	0.0194	0.0010	0.0081
Silver sagebrush	0.0161	0.0680	0.0139	0.0518
Fallow*	0.1375	0.2666	0.0669	0.1786
Crop	0.0911	0.2080	0.1018	0.2347
Cultivated	0.2286	0.1199	0.1687	0.1068
Native grass*	0.5680	0.3990	0.7238	0.3651
Tame grass	0.0837	0.1985	0.0579	0.1713
Hay	0.0050	0.0500	0.0008	0.0122
Development	0.0063	0.0251	0.0032	0.0221
Other	0.0110	0.0533	0.0042	0.0533
Road*	0.0583	0.0238	0.0044	0.0094

*Land cover variables significantly different ($P < 0.05$) between route types.

Bird data

To determine if there were differences in bird community composition, abundance, and frequency of occurrence between off-road and roadside routes, we used the associated land cover data to help explain any observed differences. Because roadside routes had more point counts, and to remove the effect of time of day on detectability, we subsampled roadside routes to include the same number of points as the paired off-road route. We included individual roadside points that most closely matched the start times of the off-road points done on the paired route. To make our data comparable to BBS-style surveys, we included all detections of birds within the 400 m point-count radius in the analyses. All birds detected during the surveys were included in the analyses except waterfowl, geese, raptors, and birds that were only detected flying over the point count station and not exhibiting territorial behaviors, e.g., singing. Birds performing aerial courtship displays or flying within the point count station were included in the analyses. Because vehicle traffic volume was very low on these roads (typically < 25 vehicles/day, C. Scobie *unpublished data*) and vegetation structure was similar between the two route types, we assumed that songbird detectability would be similar enough to allow direct comparison of bird communities between the two route types.

As is the case with BBS-style point counts, our methods did not permit a direct estimate of songbird detectability. The habitat preferences of each species were classified as obligate grassland or facultative grassland from Vickery et al. (1999) or from habitat associations based on Poole (2005) for species not classified by Vickery et al. (Table 2). Several of the species detected are considered to be at risk, either within Alberta and/or Canada (Table 2).

Prior to analysis, species abundance data at the point count level were square-root transformed to reduce the effects of superabundant and flocking species on the analysis. A preliminary ordination suggested that a unimodal model was appropriate for the data set (ter Braak and Smilauer 2002); so we used canonical correspondence analysis (CCA) to model the species-environment relationship with Canoco for Windows 4.5 (ter Braak and Smilauer 2002). We generated a preliminary CCA with all explanatory variables, i.e., native grass, tame grass, hay, cultivated agricultural crop, fallow, water, development, trees, silver sagebrush, short shrub, tall shrub, other, and roads, and used forward selection using Monte Carlo permutations to select explanatory variables. All nonsignificant ($P > 0.05$) and collinear variables were removed to produce a final CCA. Symmetric scaling was used, because this method provides a good visual portrayal of species and samples (ter Braak and Smilauer 2002). Multiple Response Permutation Procedures (MRPP) with a Euclidean distance measure were then used to test for differences in avian community composition between the route types (ter Braak and Smilauer 2002).

The magnitude of difference in detections of each species between roadside and off-road routes was assessed using indicator species analysis (ISA; Dufrene and Legendre 1997) with a Euclidean distance in PC-ORD (McCune and Mefford 1999). ISA assesses the relative abundance and frequency of occurrence of each species between treatment types, i.e., off-road versus roadside surveys (Dufrene and Legendre 1997). The significance of the resulting indicator values was tested using 999 Monte Carlo permutations. Results were considered significant at $P < 0.05$. The ratio of road to off-road indicator values for a particular species provides an estimate of the differences in abundance and frequency of occurrence between roadside and off-road survey types.

RESULTS

Within a 400 m radius of point-count centers on roadside routes, there was significantly more road coverage ($t = 31.93$, df = 282.93, $P < 0.0001$) and fallow habitat ($t = 3.38$, df = 379.76, $P < 0.001$) and significantly less native grass ($t = -4.49$, df = 459.10, $P < 0.0001$) and short shrub ($t = -3.34$, df = 339.16, $P < 0.001$). After removing records of waterfowl, geese, raptors, birds detected flying over the point-count area, and species with too few detections to reliably analyze (< four observations) from the data, the resulting data consisted of 3977 observations representing 37 species and unidentified gulls and blackbirds. These unidentified gulls and blackbirds were included in the analyses because they may be important in influencing avian composition. We included seven significant land cover variables in the canonical correspondence analysis: silver sagebrush, tame grass, crop, road, development, short shrub, and native grass (Fig. 2, Table 2). The first three axes of the species-environment relationship explained 69.1% (Axis 1 = 35.9%, Axis 2 = 19.2%, Axis 3 = 14.0%) of the variance in the data.

Obligate grassland species, including Baird's Sparrow (*Ammodramus bairdii*), the Chestnut-collared Longspur (*Calcarius ornatus*), the Grasshopper Sparrow (*Ammodramus savannarum*), the Marbled Godwit (*Limosa fedoa*), McCown's Longspur (*Rhynchophanes mccownii*), and Sprague's Pipit (*Anthus spragueii*) were strongly associated with native grassland

Table 2. Habitat preferences, habitat guild, Canadian and Albertan population status designation summary statistics, mean abundance per point count, and Indicator Values, significance (*P*) of Indicator Species Analysis and four-letter American Ornithologists Union (AOU) code for species detected on surveys in the Prairie Ecozone of southern Alberta.

Species Name	Scientific Name	AOU Code	Habitat Preferences[†]	Habitat Guild[‡]	COSEWIC and ASRD Species' Designation[‖]		Mean abundance (number/pt. count)		Indicator Values		
					Canada	Alberta	Roadside	Off-road	Roadside	Off-road	P
Blackbird spp.							0.062	0.004	2	0	0.088
Gull spp.							0.160	0.093	1	1	0.866
American Crow	*Corvus brachyrhynchos*	AMCR	Ag, Tr	F[§]	NA	S	0.138	0.009	6	2	0.085
American Robin	*Turdus migratorius*	AMRO	Ag, Hu, Tr	F[§]	NA	S	0.027	0.009	2	0	0.12
Baird's Sparrow[¶]	*Ammodramus bairdii*	BAIS	Gr	O	SC	Se	0.009	0.147	0	10	<0.001
Barn Swallow[¶]	*Hirundo rustica*	BARS	Ag, Hu, We	F[§]	Th	Se	0.071	0.000	4	0	0.008
Black-billed Magpie[¶]	*Pica hudsonia*	BBMA	Ag, Hu, Tr	F[§]	NA	S	0.089	0.013	7	0	0.002
Brown-headed Cowbird[¶]	*Molothrus ater*	BHCO	Ag, Gr, Tr	F[§]	NA	S	0.391	0.013	20	1	<0.001
Brewer's Blackbird[¶]	*Euphagus cyanocephalus*	BRBL	Ag, Hu, Sh	F	NA	S	0.267	0.129	10	1	0.003
Brewer's Sparrow	*Spizella breweri*	BRSP	Gr, Sh	O[§]	NA	Se	0.004	0.036	0	2	0.093
California Gull	*Larus californicus*	CAGU	Ag, We	F[§]	NA	S	0.049	0.009	2	0	0.156
Chestnut-collared Longspur[¶]	*Calcarius ornatus*	CCLO	Gr	O	Th	Se	0.840	1.476	11	33	<0.001
Clay-colored sparrow	*Spizella pallida*	CCSP	Sh, Gr	F	NA	S	0.151	0.116	8	4	0.282
Eastern Kingbird[¶]	*Tyrannus tyrannus*	EAKI	Ag, Hu, Sh	F	NA	S	0.071	0.013	4	0	0.012
European Starling[¶]	*Sturnus vulgarus*	EUST	Ag, Hu	F[§]	Ex	Ex	0.151	0.000	3	0	0.033
Grasshopper Sparrow	*Ammodramus savannarum*	GRSP	Gr	O	NA	Se	0.027	0.062	1	4	0.125
Horned Lark	*Eremophila alpestris*	HOLA	Gr, Ag	O	NA	S	1.711	1.893	33	40	0.128
House Sparrow[¶]	*Passer domesticus*	HOSP	Ag, Hu, Tr	F[§]	Ex	Ex	0.240	0.004	5	0	0.001
Killdeer	*Charadrius vociferous*	KILL	Gr, We, Ag	F	NA	S	0.089	0.067	4	2	0.402
Lark Bunting	*Calamospiza melanocorys*	LARB	Gr	O	NA	S	0.333	0.342	4	6	0.521
Lark Sparrow	*Chondestes grammacus*	LASP	Ag, Gr, Sh	F	NA	S	0.040	0.009	1	0	0.255
Long-billed Curlew	*Numenius americanus*	LBCU	Gr, We	O	SC	Se	0.107	0.116	4	5	0.935
Marbled Godwit[¶]	*Limosa fedoa*	MAGO	Gr, Ag, We	O	NA	S	0.129	0.259	4	11	0.031
McCown's Longspur[¶]	*Rhynchophanes mccownii*	MCLO	Gr	O	SC	Se	0.116	0.293	2	12	0.002
Mourning Dove[¶]	*Zenaida macroura*	MODO	Ag, Hu, Tr	F	NA	S	0.071	0.009	4	0	0.010
Ring-billed Gull	*Larus delawarensis*	RBGU	Ag, We	F[§]	NA	S	0.027	0.031	1	1	0.916
Ring-necked Pheasant	*Phasianus colchicus*	RPHE	Ag, Gr, Hu, Tr	F	Ex	Ex	0.013	0.009	1	0	1.000
Red-winged Blackbird[¶]	*Agelaius phoeniceus*	RWBL	Ag, Gr, We	F	NA	S	0.253	0.084	10	1	0.004
Savannah Sparrow	*Passerculus sandwichnensis*	SAVS	Gr, We	O	NA	S	0.493	0.640	15	23	0.101
Sora	*Porzana carolina*	SORA	We	F[§]	NA	Se	0.013	0.031	0	2	0.390
Sprague's Pipit[¶]	*Anthus spragueii*	SPPI	Gr	O	Th	Se	0.156	0.284	5	14	0.015

(con'd)

Upland Sandpiper	*Bartramia longicauda*	UPSA	Gr, Ag	O	NA	Se	0.036	0.053	1	2	0.686
Vesper Sparrow[¶]	*Pooecetes gramineus*	VESP	Gr, Sh	O	NA	S	0.613	0.391	27	12	0.001
Western Kingbird[¶]	*Tyrannus verticalis*	WEKI	Ag, Gr, We	F	NA	S	0.062	0.009	4	0	0.011
Western Meadowlark	*Sturnella neglecta*	WEME	Gr, Ag	O	NA	S	1.484	1.658	37	38	0.848
Willet[¶]	*Tringa semipalmata*	WILL	We, Gr	F	NA	S	0.071	0.151	2	8	0.025
Wilson's Snipe	*Gallinago delicata*	WISN	We, Gr	F	NA	S	0.049	0.053	2	3	1.000
Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*	YHBL	Ag, Gr, We	F[§]	NA	S	0.111	0.027	3	0	0.161
Yellow Warbler	*Setophaga petechia*	YWAR	Hu, Sh, We	F[§]	NA	S	0.022	0.004	2	0	0.218

[†] Ag = agricultural land, Gr = grassland, Hu = human habitation, Sh = shrubs, Tr = trees, We = wetland/marsh (Ehrlich et al. 1988)
[‡] Habitat guild classification as obligate (O) or facultative (F) grassland habitat preference (from Vickery et al. 1999 and from Poole (2005) [§] for species not classified by Vickery et al. 1999)
[|]Ex - Exotic, MR - May Be At Risk, NA - Not Assessed, NR - Not At Risk, S - Secure, SC - Special Concern, Se - Sensitive, Th - Threatened (COSEWIC – Committee on the Status of Endangered Wildlife in Canada; AESRD – Alberta Environment and Sustainable Resource Development 2010).
[¶] Species with significantly different indicator values ($P < 0.05$).

and negatively correlated with human-modified habitats, e.g., crop, tame grass, and road. Brewer's Sparrow (*Spizella breweri*) and the Lark Bunting (*Calamospiza melanocorys*) were both associated with silver sagebrush, and the Lark Bunting also was associated with tame grass. Facultative grassland and farmland birds, including the American Robin (*Turdus migratorius*), the Barn Swallow (*Hirundo rustica*), the Black-billed Magpie (*Pica hudsonia*), the Brown-headed Cowbird (*Molothrus ater*), and the Eastern Kingbird (*Tyrannus tyrannus*), were highly correlated with roads and development. Blackbird species were associated with development, and the Yellow Warbler (*Setophaga petechia*) and the House Sparrow (*Passer domesticus*), an alien species, were both associated with development and roads. The Lark Sparrow (*Chondestes grammacus*), gull species, the Yellow-headed Blackbird (*Xanthocephalus xanthocephalus*), and the California Gull (*Larus californicus*) were associated with crop land. The Clay-colored Sparrow (*Spizella pallida*), the European Starling (*Sturnus vulgaris*), the Red-winged Blackbird (*Agelaius phoeniceus*), and the Ring-necked Pheasant (*Phasianus colchicus*) responded to both crop land and road areas. Multiple Response Permutation Procedures showed that the community composition between the survey types was significantly different ($A = 0.0057$, $T = 10.4303$, $P < 0.0001$).

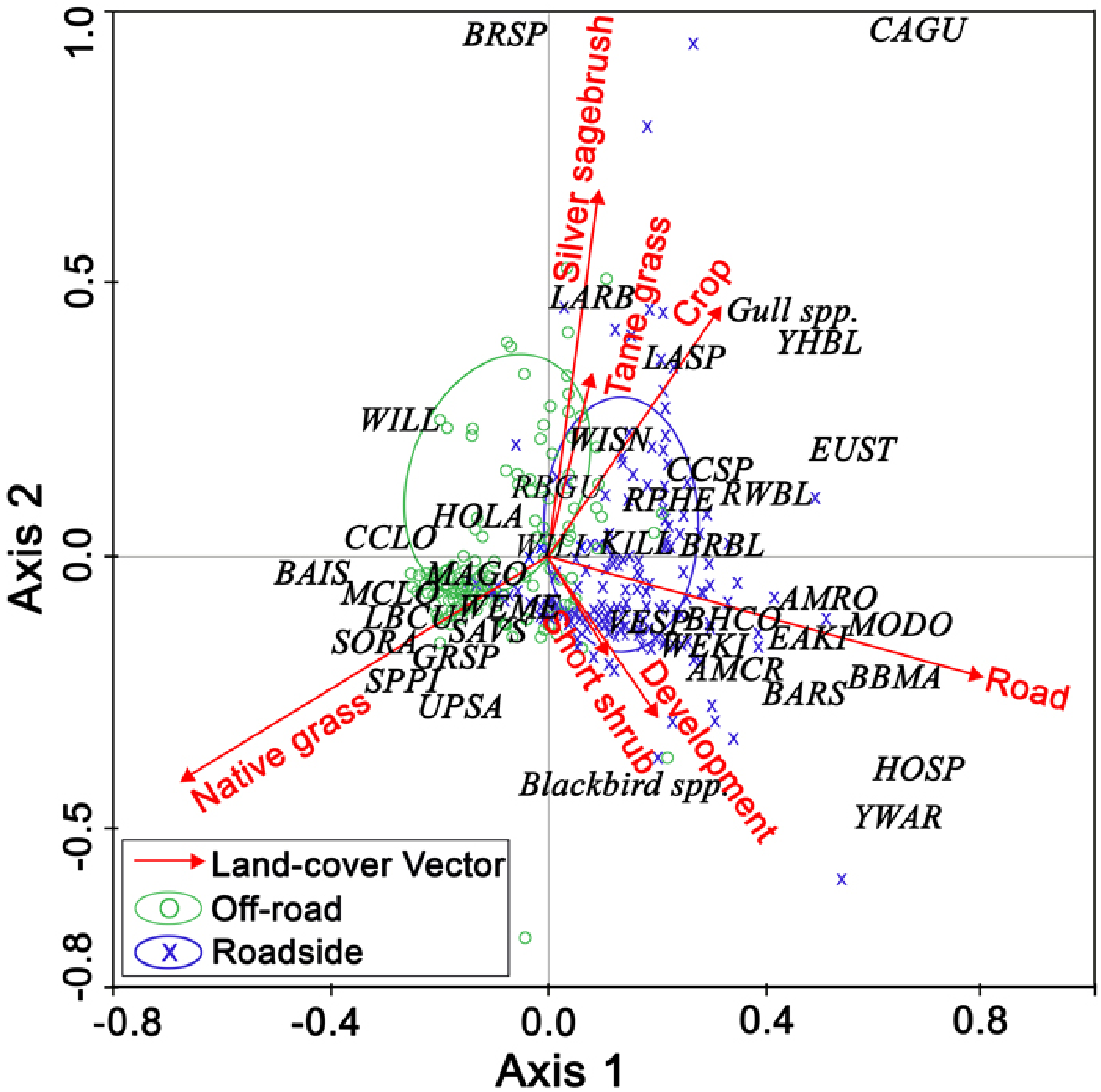
Of the 39 bird species, 17 had significantly different indicator values between route types (Fig. 3, Table 2). Six species, the Chestnut-collared Longspur, Sprague's Pipit, McCown's Longspur, the Marbled Godwit, Baird's Sparrow, and the Willet (*Tringa semipalmata*), had significant indicator values associated with off-road routes. Eleven species, the Vesper Sparrow (*Pooecetes gramineus*), the Brown-headed Cowbird, the Red-winged Blackbird, Brewer's Blackbird (*Euphagus cyanocephalus*), the Black-billed Magpie, the House Sparrow, the Eastern Kingbird, the Western Kingbird (*Tyrannus verticalis*), the Mourning Dove (*Zenaida macroura*), the Barn Swallow, and the European Starling, had significant indicator values for roadside routes. The American Crow (*Corvus brachyrhynchos*) and Blackbird spp. had high but nonsignificant indicator values ($P < 0.1$) associated with the roadside surveys, and Brewer's Sparrow, the Savannah Sparrow (*Passerculus sandwichensis*), and the Grasshopper Sparrow had high but nonsignificant indicator values for the off-road surveys.

DISCUSSION

Conducting off-road bird surveys adjacent to roadside surveys allowed us to compare bird communities and bird species' abundance, using each of the surveys. Earlier investigations have found that some grassland obligate species are more prevalent on surveys away from roads (Davis and Duncan 1999, Vickery et al. 1999, Sutter et al. 2000); however, few have collected land cover information to potentially explain observed differences. In our study, off-road routes were composed of more native grassland and short shrubs, whereas roadside routes were dominated by roads and land uses associated with crop farming. These land cover differences led to 17 of 39 (44%) bird species that differed significantly in relative abundance and frequency of occurrence between the route types. Road development is often associated with habitats that have been converted from native vegetation to habitats typical of farmed landscapes (Boren et al. 1999, Keller and Scallan 1999) and, indeed, the proportion of cultivated land was closely correlated with proportion of road.

Avian community composition differed significantly between the off-road and roadside surveys. The bird community associated with off-road routes was dominated by species typical of native grassland habitats. Among the six species that had greater indicator values associated with off-road routes, four are listed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) or under the Canadian federal Species at Risk Act (SARA), namely, Sprague's Pipit, Baird's Sparrow, the Chestnut-collared Longspur, and McCown's Longspur, and all, except the Willet, are obligate grassland species. Many obligate grassland birds tend to have lower abundance in, or are absent in, smooth brome (*Bromus inermis*), crested wheatgrass, and alfalfa hayfields and pastures (Davis and Duncan 1999, Robbins and Dale 1999, Green et al. 2002), which are typical of landscapes dominated by non-native land cover types (Gratto-Trevor 2000, Sutter et al. 2000, Dechant et al. 2003). Marbled Godwits and Willets prefer habitats with native grassland and shallow, seasonal wetlands

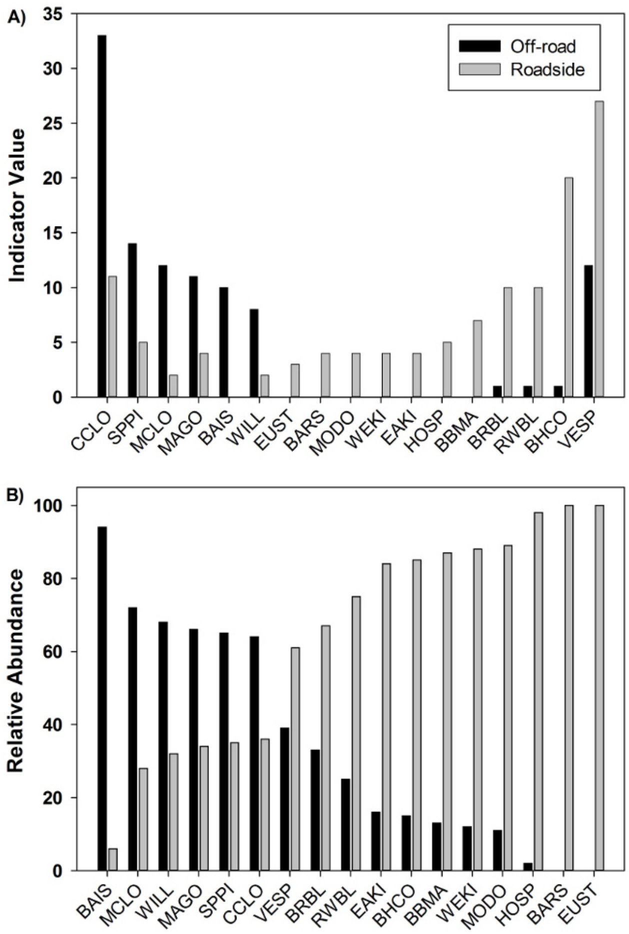
Fig. 2. Canonical Correspondence Analysis (CCA) ordination plot with 67% confidence ellipses for 37 bird species plus two bird groups (Blackbird and Gull spp.), counted along off-road (n = 225 point count stations) and roadside surveys (n = 225 point counts), in the Prairie Ecozone of Alberta, Canada. Four-letter codes and scientific names for species are listed in Table 2. Vectors indicate direction and strength (length) of relationships between species and explanatory land-cover (habitat-type) variables.



(Lowther et al. 2001), which are likely more abundant on off-road routes, where these wetlands have not been filled in or degraded to the same extent as in cultivated areas. However, we did not detect differences in the area of wetlands between survey types. McCown's Longspur and the Chestnut-collared Longspur prefer short, sparse to moderately vegetated native habitat for nesting and foraging and therefore may avoid the dense vegetation often associated with road ditches (Johnson et al. 2004).

The bird community associated with roadside surveys included common species and those typical of farmland and other human-modified habitats. The greater occurrence of these species on roadside routes is because of higher amounts of agricultural land uses and anthropogenic development, e.g., farms and granaries. Although we did not detect differences in the amount of development in the direct comparison of the survey types, it was a significant predictor of the bird community. The Barn Swallow, the European Starling, and the House Sparrow exist in grassland landscapes only where human-built structures are present, and they are rare in extensive tracts of grassland, where such structures are also rare (Lowther and Cink 2006). Similarly, nest predators or parasitic-nesting species such as the Black-billed Magpie, Brewer's Blackbird, and the Brown-headed Cowbird are

Fig. 3. Community indicator values (A) and relative abundance (B) for species with significant ($P > 0.05$) differences in indicator values, combining both abundance and frequency of occurrence, in roadside (n = 225 point counts) and off-road (n = 225 point counts) surveys in the Prairie Ecozone of Alberta. To generate the relative abundance, absolute abundance measures were rescaled so the total of the two abundances (off-road and roadside) were equal to 100. See Table 2 for four-letter species codes.



frequently found in higher densities in human-modified habitats, along fence lines and at habitat edges (Lowther 1993, Trost 1999, Davis and Sealy 2000, Martin 2002), and several of these species were associated with roads in our study. The higher abundance and frequency of occurrence of Red-winged Blackbird on roadside surveys is possibly because of a greater abundance of dense marsh vegetation around the relatively deep water bodies that form in ditches and livestock watering holes (Niemuth et al. 2007, Safratowich et al. 2008) in which this species nests, and near cropland (Yasukawa and Searcy 1995) in which it forages. Similar to the findings of other studies in the Canadian grasslands, we found that the Vesper Sparrow was more prevalent on roadside routes (Sutter et al. 2000). This species is classified as obligate grassland by Vickery et al. (1999), but may be more of a moderate grassland generalist that is responding to structural attributes of the habitat (open areas with short, sparse, and patchy vegetation, and taller shrubs or fence posts for song perches) found more commonly on roadside routes (Dechant et al. 2003).

The significant differences in abundance and frequency of occurrence between roadside and off-road surveys for nearly half of the species surveyed have important conservation implications. Population and trend estimates and species distribution models based solely on roadside surveys in the BBS may overestimate the population size of some species and underestimate the size of others. This may be exacerbated by differences in the magnitude and rate of habitat change because of anthropogenic impacts near or away from roads, which could impact trend estimates for these species. The BBS also samples different bird communities than those found in less disturbed areas of the landscape, because roads are often associated with areas of greater development. Underestimating the population size and overestimating the declining trend of several obligate grassland birds is potentially good news for the status of these species. However, their low occurrence in roadside surveys likely makes it more difficult to accurately detect population changes over time and to construct distribution models for these species (Bart et al. 2004). Most species that were more abundant on roadside routes are of low conservation concern, e.g., House Sparrow, European Starling, Black-billed Magpie. However, there may be species for which abundance overestimation on BBS routes is problematic, including the Vesper Sparrow. Additionally, aerial insectivores, the Eastern Kingbird, the Western Kingbird, and the Barn Swallow, that are undergoing steep population declines across North America (Böhning-Gaese et al. 1993, Rich et al. 2004, Sauer et al. 2007) were more abundant at roadsides. Although there are no examples of roadside bias affecting the conservation status of a species, population estimates and trends of grassland species that are based on BBS data warrant further critical examination.

BBS-style surveys may not representatively sample all habitats in the landscape, particularly habitats occurring away from roads (Thogmartin et al. 2006, Harris and Haskell 2007). Representative sampling to develop more robust conservation metrics, e.g., population estimates, trends, and species distribution models, could be achieved in at least two ways. First, random or systematic sampling across the landscape would be more representative of the available habitat. Random sampling would, however, be very difficult to achieve, in part because of logistics involved in gaining access to private land and traveling to random locations. Although our sampling was not completely random, the off-road routes surveyed a relatively representative sample of habitats in this landscape. A second option would be to better understand bird abundance in each habitat type and use information on habitat area to extrapolate across the landscape. This would provide a close connection between the species and what may be their greatest threat, habitat loss. The disadvantage of this latter approach is that it is very rare to have detailed habitat information for large areas. A hybrid approach may be most feasible, in which data are collected from both road and off-road routes (Hanowski and Niemi 1995). The data could then be weighted in models based on the amount of habitat near roads and the amount away from roads in the broader landscape. Another consequence of lower prevalence of obligate grassland species near roads is that any increase in road density is likely to lead to direct loss of their habitat. With increasing development pressure, e.g., oil and gas development and transportation infrastructure, and loss and fragmentation of the remaining native habitat in the Prairie Ecozone of Alberta, and in many grassland regions of North America, it is likely that habitats that co-occur with roads will increase. Consequently, those species dependent on native habitats will likely decline as they become restricted to smaller patches of suitable habitat (Herkert 1994, Johnson and Igl 2001, Davis 2004).

Our results are potentially limited by the relatively small geographic area in which this study was conducted, i.e., only in the southern portion of the grasslands in Alberta. Results from our study may differ from those in other parts of grassland species' ranges, i.e., other Canadian provinces, the United States, if the distribution of habitat near and away from roads is different in those other areas. Differences in the magnitude and rate of habitat change in these areas could also potentially influence population trends of the same species. Our results should be tested against similar data from other areas in which similar grassland bird communities occur and against potentially developing species distribution models. However, our results are still important, because our study was conducted in a large part of the Canadian range of many grassland-obligate species, and is therefore important for efforts directed at the conservation of grassland birds and their habitat in Canada.

BBS data have been crucial in showing population trends of many species across years (Boren et al. 1999, Sauer et al. 2007, but see Betts et al. 2007), but may be less reliable in predicting the occurrence and distribution of species over the entire landscape, especially in relatively undisturbed sites with few roads from which to survey, and for estimating overall population sizes. BBS-style roadside surveys may also be poor at documenting rare or endangered species, especially those that occupy habitats not sampled well with roadside surveys. Of the eight species we analyzed that are considered at risk in Alberta or Canada, four associated with native grassland were found in higher abundance on off-road routes. Conservation programs are often targeted at these declining grassland-obligate species, and roadside surveys may not be sufficient for providing reliable data for the successful implementation of such programs, especially for species that inhabit native grasslands. Accounting for bias from roadside counts could help focus conservation efforts where they are needed the most, particularly if some species are not declining as quickly as estimated based on roadside counts.

CONCLUSION

Surveys performed away from roads revealed substantially different grassland bird communities than surveys performed along roads. This difference in bird communities largely reflected differences in habitats between the two survey types. The use of roadside surveys, such as BBS, to estimate population trends, sizes, or species distributions could result in large errors unless corrections are developed for the influence of sampling only from roadsides. Correction for this bias will require sampling that is representative of locations and habitats across the landscape, including samples away from roads. Further modeling, using data sets like ours, will determine what off-road sampling effort is required to develop these corrections and, ultimately, accurate population, trend, and distribution estimates.

Responses to this article can be read online at:
http://www.ace-eco.org/issues/responses.php/624

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LITERATURE CITED

Alberta Environment and Sustainable Resource Development. 2010. *Wild species status search.* Alberta Environment and Sustainable Resource Development, Edmonton, Alberta, Canada. [online] URL: http://srd.alberta.ca/FishWildlife/SpeciesAtRisk/WildSpeciesStatusSearch.aspx

Askins, R. A., F. Chavez-Ramirez, B. C. Dale, C. A. Haas, J. R. Herkert, F. L. Knopf, and P. D. Vickery. 2007. Conservation of grassland birds in North America: understanding ecological processes in different regions. *Ornithological Monographs* 64:1-46.

Bart, J., K. P. Burnham, E. H. Dunn, C. M. Francis, and C. J. Ralph. 2004. Goals and strategies for estimating trends in landbird abundance. *Journal of Wildlife Management* 68:611-626. http://dx.doi.org/10.2193/0022-541X(2004)068[0611:GASFET]2.0.CO;2

Bart, J., M. Hofshen, and B. G. Peterjohn. 1995. Reliability of the Breeding Bird Survey: effects of restricting surveys to roads. *Auk* 112:758-761.

Benítez-López, A., R. Alkemade, and P. A. Verweij. 2010. The impacts of roads and other infrastructure on mammal and bird populations: a meta-analysis. *Biological Conservation* 143:1307-1316. http://dx.doi.org/10.1016/j.biocon.2010.02.009

Betts, M. G., D. Mitchell, A. W. Diamond, and J. Bety. 2007. Uneven rates of landscape change as a source of bias in roadside wildlife surveys. *Journal of Wildlife Management* 71:2266-2273. http://dx.doi.org/10.2193/2006-004

Böhning-Gaese, K., M. L. Taper, and J. H. Brown. 1993. Are declines in North American insectivorous songbirds due to causes on the breeding range? *Conservation Biology* 7:76-86. http://dx.doi.org/10.1046/j.1523-1739.1993.07010076.x

Boren, J. C., D. M. Engle, M. W. Palmer, R. E. Masters, and T. Criner. 1999. Land use change effects breeding bird community composition. *Journal of Range Management* 52:420-430. http://dx.doi.org/10.2307/4003767

Brotons, L., W. Thuiller, M. B. Araújo, and A. H. Hirzel. 2004. Presence-absence versus presence-only modelling methods for predicted bird habitat suitability. *Ecography* 27:437-448. http://dx.doi.org/10.1111/j.0906-7590.2004.03764.x

Bystrack, D. 1981. The North American Breeding Bird Survey. *In* C. J. Ralph and J. M. Scott, editors. *Studies in Avian Biology* 6:34-41.

Coppedge, B. R., D. M. Engle., R. E. Masters, and M. S. Gregory. 2001. Avian response to landscape change in fragmented southern Great Plains grasslands. *Ecological Applications* 11:47-59. http://dx.doi.org/10.1890/1051-0761(2001)011[0047:ARTLCI]2.0.CO;2

Davis, S. K. 2004. Area sensitivity in grassland passerines: effects of patch size, patch shape, and vegetation structure on bird abundance and occurrence in southern Saskatchewan. *Auk* 121:1130-1145.

Davis, S. K., and D. C. Duncan. 1999. Grassland songbird occurrence in native and crested wheatgrass pastures of southern Saskatchewan. *Studies in Avian Biology* 19:211-218.

Davis, S. K., and S. G. Sealy. 2000. Cowbird parasitism and nest predation in fragmented grasslands of southwestern Manitoba. Pages 220-228 *in* J. N. M. Smith, T. L. Cook, S. I. Rothstein, S. K. Robinson, and S. G. Sealy, editors. *Ecology and management of cowbirds and their hosts: studies in the conservation of North American passerine birds.* University of Texas Press, Austin, Texas, USA.

Dechant, J. A., M. F. Dinkins, D. H. Johnson, L. D. Igl, C. M. Goldade, and B. R. Euliss. 2003. *Effects of management practices on grassland birds: Vesper Sparrow.* Northern Prairie Wildlife Research Center, Jamestown, North Dakota, USA. [online] URL: http://www.npwrc.usgs.gov/resource/literatr/grasbird/vesp/vesp.htm

Dufrene, M., and P. Legendre. 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. *Ecological Monographs* 67:345-366.

Fletcher, Jr., R. J., and R. R. Koford. 2003. Spatial responses of Bobolinks (*Dolochonyx oryzivorus*) near different types of edges in northern Iowa. *Auk* 120:799-810.

Forman, R. T., and L. E. Alexander. 1998. Roads and their major ecological effects. *Annual Review of Ecology and Systematics* 29:207-231. http://dx.doi.org/10.1146/annurev.ecolsys.29.1.207

Forman, R. T., B. Reineking, and A. M. Hersperger. 2002. Road traffic and nearby grassland bird patterns in a suburbanizing landscape. *Environmental Management* 29:782-800. http://dx.doi.org/10.1007/s00267-001-0065-4

Francis, C. M., J. M. Bart, E. H. Dunn, K. P. Burnham, and C. J. Ralph. 2005. Enhancing the value of the Breeding Bird Survey: reply to Sauer et al. (2005). *Journal of Wildlife Management* 69:1327-1332. http://dx.doi.org/10.2193/0022-541X(2005)69[1327:ETVOTB]2.0.CO;2

Gauthier, D. A., and E. B. Wiken. 2003. Monitoring the conservation of grassland habitats, prairie ecozone, Canada. *Environmental Monitoring and Assessment* 88:343-364. http://dx.doi.org/10.1023/A:1025585527169

Gratto-Trevor, C. L. 2000. Marbled Godwit (*Limosa fedoa*). *In* A. Poole, editor. *The birds of North America online.* Cornell Lab of Ornithology, Ithaca, New York, USA. [online] URL: http://bna.birds.cornell.edu/bna/species/492

Green, M. T., P. E. Lowther, S. L. Jones, S. K. Davis, and B. C. Dale. 2002. Baird's Sparrow (*Ammodramus bairdii*). *In* A. Poole, editor. *The birds of North America online.* Cornell Lab of Ornithology, Ithaca, New York, USA. [online] URL: http://bna.birds.cornell.edu/bna/species/638

Guisan, A., and W. Thuiller. 2005. Predicting species distribution: offering more than simple habitat models. *Ecology Letters* 8:993-1009. http://dx.doi.org/10.1111/j.1461-0248.2005.00792.x

Hanowski, J. M., and G. J. Niemi. 1995. A comparison of on- and off-road bird counts: do you need to go off road to count birds accurately? *Journal of Field Ornithology* 66:469-483.

Harris, J. B. C., and D. G. Haskell. 2007. Land cover sampling biases associated with roadside bird surveys. *Avian Conservation and Ecology - Écologie et conservation des oiseaux* 2(2): 12. [online] URL: http://www.ace-eco.org/vol2/iss2/art12/

Herkert, J. R. 1994. The effects of habitat fragmentation on Midwestern grassland bird communities. *Ecological Applications* 4:461-471. http://dx.doi.org/10.2307/1941950

Hutto, R. L., S. J. Hell, J. F. Kelly, and S. M. Pletschet. 1995. A comparison of bird detection rates derived from on-road versus off-road point counts in northern Montana. Pages 103-110 *in* C. J. Ralph, J. R. Sauer, and S. Droege, editors. *Monitoring bird populations by point counts.* U.S. Forest Service General Technical Report PSW-GTR-149, Albany, California, USA.

Johnson, D. H., and L. D. Igl. 2001. Area requirements of grassland birds: a regional perspective. *Auk* 118:24-34.

Johnson, D. H., L. D. Igl, and J. A. Dechant Shaffer, series coordinators. 2004. *Effects of management practices on grassland birds.* Northern Prairie Wildlife Research Center Online, Jamestown, North Dakota, USA. [online] URL: http://www.npwrc.usgs.gov/resource/literatr/grasbird/index.htm

Kadmon, R., O. Farber, and A. Danin. 2004. Effect of roadside bias on the accuracy of predictive maps produced by bioclimatic models. *Ecological Applications* 14:401-413. http://dx.doi.org/10.1890/02-5364

Keller, C. M. E., and M. R. Fuller. 1995. Comparisons of birds detected from roadside and off-road point counts in the Shenandoah National Park. Pages 111-115 *in* C. J. Ralph, J. R. Sauer, and S. Droege, editors. *Monitoring bird populations by point counts.* U.S. Forest Service General Technical Report PSW-GTR-149, Albany, California, USA.

Keller, C. M. E., and J. T. Scallan. 1999. Potential roadside biases due to habitat changes along breeding bird survey routes. *Condor* 101:50-57. http://dx.doi.org/10.2307/1370445

Koper, N., D. J. Walker, and J. Champagne. 2009. Nonlinear effects of distance to habitat edge on Sprague's Pipits in southern Alberta, Canada. *Landscape Ecology* 24:1287-1297. http://dx.doi.org/10.1007/s10980-009-9375-3

Lima, S. L., and T. J. Valone. 1991. Predators and avian community organization: an experiment in a semi-desert grassland. *Oecologia* 86:105-112. http://dx.doi.org/10.1007/BF00317396

Lowther, P. E. 1993. Brown-headed Cowbird (*Molothrus ater*). *In* A. Poole, editor. *The birds of North America online.* Cornell Lab of Ornithology, Ithaca, New York, USA. [online] URL: http://bna.birds.cornell.edu/bna/species/047

Lowther, P. E., and C. L. Cink. 2006. House Sparrow (*Passer domesticus*). *In* A. Poole, editor. *The birds of North America online*.

Cornell Lab of Ornithology, Ithaca, New York, USA. http://bna.birds.cornell.edu/bna/species/012/articles/introduction

Lowther, P. E., H. D. Douglas III, and C. L. Gratto-Trevor. 2001. Willet (*Tringa semipalmata*). *In* A. Poole, editor. *The birds of North America online*. Cornell Lab of Ornithology, Ithaca, New York, USA. [online] URL: http://bna.birds.cornell.edu/bna/species/579/articles/introduction

Martin, S. G. 2002. Brewer's Blackbird (*Euphagus cyanocephalus*). *In* A. Poole, editor. *The birds of North America online.* Cornell Lab of Ornithology, Ithaca, New York, USA. http://bna.birds.cornell.edu/bna/species/616/articles/introduction

McCarthy, K. P., R. J. Fletcher Jr., C. T. Rota, and R. L. Hutto. 2012. Predicting species distributions from samples collected along roadsides. *Conservation Biology* 26:68-77. http://dx.doi.org/10.1111/j.1523-1739.2011.01754.x

McCune, B., and M. J. Mefford. 1999. *PC-ORD. Multivariate analysis of Ecological Data version 4.20.* MjM Software, Gleneden Beach, Oregon, USA.

Murray, L. D., C. A. Ribic, W. E. Thogmartin, and M. G. Knutson. 2008. Accuracy assessment of predictive models of grassland bird abundances in the prairie hardwood transition bird conservation region. *Condor* 110:747-755. http://dx.doi.org/10.1525/cond.2008.8610

Niemuth, N. D., A. L. Dahl, M. E. Estey, and C. R. Loesch. 2007. Representation of landcover along Breeding Bird Survey routes in the northern plains. *Journal of Wildlife Management* 71:2258-2265. http://dx.doi.org/10.2193/2006-281

Niemuth, N. D., M. E. Estey, and C. R. Loesch. 2005. Developing spatially explicit habitat models for grassland bird conservation planning in the prairie pothole region of North Dakota. Pages 469-477 *in* C. J. Ralph and T. D. Rich, editors. *Bird conservation implementation and integration in the Americas: proceedings of the Third International Partners in Flight Conference*, 2002 March 20-24, Asilomar, California, USA. Volumes 1 and 2. General Technical Report PSW-GTR-191. Pacific Southwest Research Station, U.S. Forest Service, Albany, California, USA.

Peterjohn, B. G., and J. R. Sauer. 1999. Population status of North American grassland birds from the North American Breeding Bird Survey, 1966-1996. *Studies in Avian Biology* 19:27-44.

Poole, A., editor. 2005. *The birds of North America online.* Cornell Laboratory of Ornithology, Ithaca, New York, USA. [online] URL: http://bna.birds.cornell.edu/bna/

R Development Core Team. 2012. *R: a language and environment for statistical computing.* R Foundation for Statistical Computing, Vienna, Austria. [online] URL: http://www.R-project.org

Rich, T. D., C. J. Beardmore, H. Berlanga, P. J. Blancher, M. S. W. Bradstreet, G. S. Butcher, D. W. Demarest, E. H. Dunn, W. C. Hunter, E. E. Iñigo-Elias, J. A. Kennedy, A. M. Martell, A. O. Panjabi, D. N. Pashley, K. V. Rosenberg, C. M. Rustay, J. S. Wendt, and T. C. Will. 2004. *Partners in Flight North American Landbird Conservation Plan.* Cornell Lab of Ornithology, Ithaca, New York, USA.

Robbins, C. S., J. R. Sauer, R. S. Greenburg, and S. Droege. 1989. Population declines in North American birds that migrate to the neotropics. *Proceedings of the National Academy of Science U.S. A.* 86:7658-7662. http://dx.doi.org/10.1073/pnas.86.19.7658

Robbins, M. B., and B. C. Dale. 1999. Sprague's Pipit (*Anthus spragueii*). *In* A. Poole, editor. *The Birds of North America online.* Cornell Lab of Ornithology, Ithaca, New York, USA. [online] URL: http://bna.birds.cornell.edu/bna/species/439

Rotenberry, J. T., and S. T. Knick. 1995. Evaluation of bias in roadside point count surveys of passerines in shrubsteppe and grassland habitats in southwestern Idaho. Pages 99-101 *in* C. J. Ralph, J. R. Sauer, and S. Droege, editors. *Monitoring bird populations by point counts.* U.S. Forest Service General Technial Report PSW-GTR-149, Albany, California, USA.

Safratowich, B., G. M. Linz, W. H. Bleier, and H. J. Homan. 2008. Avian use of rural roadsides with cattail (*Typha* spp.). *American Midland Naturalist* 159:162-171. http://dx.doi.org/10.1674/0003-0031(2008)159[162:AUORRW]2.0.CO;2

Samson, F. B., and F. Knopf. 1994. Prairie conservation in North America. *Bioscience* 44:418-421. http://dx.doi.org/10.2307/1312365

Sauer, J. R., J. E. Fallon, and R. Johnson. 2003. Use of North American Breeding Bird Survey data to estimate population change for bird conservation regions. *Journal of Wildlife Management* 67:372-389. http://dx.doi.org/10.2307/3802778

Sauer, J. R., W. A. Link, J. D. Nichols, and J. A. Royle. 2005. Using the North American Breeding Bird Survey as a tool for conservation: a critique of Bart et al. (2004). *Journal of Wildlife Management* 69:1321-1326. http://dx.doi.org/10.2193/0022-541X(2005)69[1321:UTNABB]2.0.CO;2

Sauer, J. R., J. E. Hines, and J. Fallon. 2007. *The North American Breeding Bird Survey, results and analysis 1966-2006.* Version 10.13.2007. USGS Patuxent Wildlife Research Center, Laurel, Maryland, USA. [online] URL: http://www.mbr-pwrc.usgs.gov/bbs/bbs2006.html

Scott, J. M., P. J. Heglund, M. L. Morrison, J. B. Haufler, M. G. Raphael, W. A. Wall, and F. B. Samson, editors. 2002. *Predicting species occurrences: issues of accuracy and scale.* Island Press, Washington, D.C., USA.

Spellerberg, I. F. 1998. Ecological effects of roads and traffic: a literature review. *Global Ecology and Biogeography Letters* 7:317-333. http://dx.doi.org/10.2307/2997681

Sutter, G. C., S. K. Davis, and D. C. Duncan. 2000. Grassland songbird abundance along roads and trails in southern Saskatchewan. *Journal of Field Ornithology* 71:110-116.

Syfert, M. M., M. J. Smith, and D. A. Coomes. 2013. The effects of sampling bias and model complexity on the predictive performance of MaxEnt species distribution models. *PLoS ONE* 8(2):e55158. http://dx.doi.org/10.1371/journal.pone.0055158

ter Braak, C. J. F., and P. Smilauer. 2002. *CANOCO Reference Manual and CanoDraw for Windows User's Guide: software for Canonical Community Ordination (Version 4.5).* Microcomputer Power, Ithaca, New York, USA.

Thogmartin, W. E., J. R. Sauer, and M. G. Knutson. 2004. A hierarchical spatial model of avian abundance with application to Cerulean Warblers. *Ecological Applications* 14:1766-1779.

http://dx.doi.org/10.1890/03-5247

Thogmartin, W. E., F. P. Howe, F. C. James, D. H. Johnson, E. T. Reed, J. R. Sauer, and F. R. Thompson III. 2006. A review of the population estimation approach of the North American Landbird Conservation Plan. *Auk* 123:892-904. http://dx.doi.org/10.1642/0004-8038(2006)123[892:AROTPE]2.0.CO;2

Trost, C. H. 1999. Black-billed Magpie (*Pica hudsonia*). *In* A. Poole, editor. *The birds of North America online.* Cornell Lab of Ornithology. Ithaca, New York, USA. [online] URL: http://bna.birds.cornell.edu/bna/species/389/articles/introduction

Veech, J. A. 2006. A comparison of landscapes occupied by increasing and decreasing populations of grassland birds. *Conservation Biology* 20: 1422-1432. http://dx.doi.org/10.1111/j.1523-1739.2006.00487.x

Vickery, P. D., P. L. Tubaro, J. M. Cardoso da Silva, B. G. Peterjohn, J. R. Herkert, and R. B. Cavalcanti. 1999. Conservation of grassland birds in the Western Hemisphere. *Studies in Avian Biology* 19:2-26.

Wiken, E. B., D. A. Gauthier, I. B. Marshall, K. Lawton, and H. Hirvonen. 1996. *A perspective on Canada's ecosystems: an overview of the terrestrial and marine ecozones.* Canadian Council on Ecological Areas (CCEA). Report No. 14. Ottawa, Ontario, Canada. [online] URL: http://www.ccea.org/Downloads/en_papers_occasional14.pdf

Yasukawa, K., and W. A. Searcy. 1995. Red-winged Blackbird (*Agelaius phoeniceus*). *In* A. Poole, editor. *The birds of North America online.* Cornell Lab of Ornithology, Ithaca, New York, USA. [online] URL: http://bna.birds.cornell.edu/bna/species/184/articles/introduction

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