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RESEARCH ARTICLE

How well do route survey areas represent landscapes at larger spatial extents? An analysis of land cover composition along Breeding Bird Survey routes

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ABSTRACT
The occurrence of birds in a survey unit is partly determined by the habitat present. Moreover, some bird species preferentially avoid some land cover types and are attracted to others. As such, land cover composition within the 400 m survey areas along a Breeding Bird Survey (BBS) route clearly influences the species available to be detected. Ideally, to extend survey results to the larger landscape, land cover composition within the survey area should be similar to that at larger spatial extents defining the landscape. Such representativeness helps minimize possible roadside effects (bias), here defined as differences in bird species composition and abundance along a roadside as compared to a larger surrounding landscape. We used land cover data from the 2011 National Land Cover Database to examine representativeness of land cover composition along routes. Using ArcGIS, the percentages of each of 15 land cover types within 400 m buffers along 2,696 U.S. BBS routes were calculated and compared to percentages in 2 km, 5 km, and 10 km buffers surrounding each route. This assessment revealed that aquatic cover types and highly urbanized land tend to be slightly underrepresented in the survey areas. Two anthropogenic cover types (pasture/hay and cropland) may be slightly overrepresented in the survey areas. Over all cover types, 92% of the 2,696 routes exhibited "good" representativeness, with $<$5 percentage points per cover type difference in proportional cover between the 400 m and 10 km buffers. This assessment further supports previous research indicating that any land-cover-based roadside bias in the bird data of the BBS is likely minimal.

Keywords: anthropogenic, bird survey, conservation, habitat, land cover, landscape, survey unit

¿En qué medida las áreas de muestreo a lo largo de las rutas representan a los paisajes de mayor extensión espacial? Un análisis de la composición de la cobertura del paisaje a lo largo de las rutas del Conteo de Aves Reproductivas.

RESUMEN
La presencia de aves en una unidad de muestreo está en parte determinada por el hábitat presente. Más aún, algunas especies de aves prefieren evitar algunos tipos de cobertura del suelo y son atraídas por otros. De tal modo, la composición de la cobertura del suelo adentro del área de muestreo de 400 m a lo largo de una ruta del Conteo Reproductiva de Aves (BBS por sus siglas en inglés) claramente influencia las especies disponibles para ser detectadas. Idealmente, para extender los resultados del muestreo al paisaje circundante, la composición de la cobertura del suelo adentro del área de muestreo debería ser similar a aquella de mayor extensión espacial a escala de paisaje. Esta representatividad ayuda a minimizar los posibles efectos del borde de la ruta (sesgo), definidos aquí como la diferencia en composición y abundancia de especies de aves a lo largo del borde de la ruta en comparación con un paisaje circundante más amplio. Usamos datos de la cobertura del suelo de la Base de Datos Nacional de Cobertura del Suelo del 2011 para examinar la representatividad de la composición de la cobertura del suelo a lo largo de las rutas. Usando ArcGIS, calculamos el porcentaje de cada uno de los 15 tipos de cobertura del suelo adentro de un buffer de 400 m a lo largo de 2,696 rutas del BBS de EEUU y lo comparamos con el porcentaje adentro de un buffer de 2, 5 y 10 km circundantes a cada ruta. Esta evaluación reveló que los tipos de cobertura acuática y las áreas altamente urbanizadas tienden a estar ligeramente sub-representados en las áreas de muestreo. Dos tipos de cobertura antropogénica (pastura/campos de heno y tierras de cultivo) podrían estar ligeramente sobre-representados en las áreas de muestreo. Considerando todos los tipos de cobertura, 92% de las 2,696 rutas mostraron una "buena" representatividad, con una diferencia $<$5% por tipo de cobertura en términos de proporción entre un buffer de 400 m y uno de 10 km. Esta evaluación apoya a otras investigaciones previas que indican que cualquier sesgo en los datos de aves del BBS derivado de la cobertura del suelo a lo largo de las rutas es probablemente mínimo.

Palabras clave: antropogénico, estudio de aves, conservación, hábitat, cubierta de tierra, paisaje, unidad de encuesta

INTRODUCTION

The North American Breeding Bird Survey (BBS) is one of the most spatially and temporally extensive vertebrate monitoring programs in the world. Data from the BBS are used extensively in basic research and applied conservation. One of the primary uses is in estimating regional-level population trends by scientists at the U.S. Geological Survey and the Canadian Wildlife Service to inform bird population management and conservation efforts (Hudson et al. 2017, Rosenberg et al. 2017). The BBS is the preeminent source of data for bird population monitoring in North America. As such, it is imperative that the BBS survey design is routinely evaluated, particularly given that the survey sample units change to some extent over time. New routes can be added to increase sample density and improve subsequent trend estimates, while some existing routes may be discontinued or reconfigured because of safety concerns.

One aspect of BBS survey design to periodically reevaluate is how well the route survey areas represent landscapes at larger spatial extents (U.S. Geological Survey 2007, Veech et al. 2012). Landscapes are often dynamic, with human-induced and naturally caused changes occurring over time. Moreover, anthropogenic changes might be more likely along roadsides than in areas far from roads (Forman and Alexander 1998, Forman and Deblinger 2000, Hawbaker and Radeloff 2004, Coffin 2007), a potential concern for any road-based survey. Even when roadside landscapes are relatively static, it is desirable that the survey or sampling units are representative of land cover composition (i.e. variety of habitats) of a greater spatial area. Certain species will either occur in the unit or not, depending in part on the availability of appropriate habitat. To some extent, bird data collected along a route are more likely to be representative of the avian fauna within the larger surrounding landscape (or region) if the survey units themselves have representative habitat. As such, population trend estimates derived from a set of routes are more likely to be trustworthy when the habitat types along the routes represent well the habitat composition in the greater surrounding landscape or region.

In many survey designs, sampling representativeness is obtained by random placement of survey units; however, the BBS cannot achieve true random sampling because survey units are, by necessity, restricted to roadsides. Nonetheless, for most types of land cover, survey units of the BBS likely are representative of larger surrounding landscapes. Veech et al. (2012) examined habitat representation along BBS routes within the conterminous United States using spatially referenced data from the 2001 version of the National Land Cover Database (NLCD). Their analysis revealed that the percentages of most land cover types within the nominal survey area of a BBS route (400 m area on both sides of the road extending the length of the route) were similar to the percentages found at larger spatial extents out to distances of a few kilometers or more.

Landscapes have changed since the 2001 database, and the NLCD is evolving to become more accurate in classifying land cover types (Homer et al. 2015). Given the changes in BBS routes, landscapes, and availability of land cover data, it is appropriate to reconsider habitat representation along BBS routes. Here, we use land cover data from NLCD 2011, the most recent version of NLCD data available at the time of our analysis. The NLCD is one of the most comprehensive and high-resolution land cover databases available (Jin et al. 2013, Homer et al. 2015). In addition to using an updated land cover database, we also improve upon Veech et al. (2012) by limiting our assessment to only those BBS routes ($\sim$2,700) that provide annual data suitable for estimating bird population trends. The previous study included a larger set of 3,230 routes, some of which are not used for trend estimation because they are "experimental" (e.g., the -800 and -900 series). As before, we examine the representativeness of 15 land cover types along each route. The present study is also based on the most accurate digitized paths of each route. As such, our study is an assessment of whether the routes most relevant to bird population monitoring are representative sampling units, with roadside land cover that is similar to the land cover in the surrounding landscape.

METHODS

Land Cover Data

Although >5,000 BBS routes have been established and surveyed at one time or more within the contiguous United States, we limited our evaluation to 2,696 routes that were sampled at least once between 2009 and 2011, with corresponding route bird data suitable for trend analyses (Pardieck et al. 2015). The period 2009–2011 corresponds to the date of our land cover data (see below) and provides insight into whether the habitats of the subset of routes being sampled are representative of the larger landscape. GIS shape files of the route paths were downloaded from http://www.mbr-pwrc.usgs.gov/bbs/geographic_information/GIS_shapefiles_2012.html (shape files were not available for 19 routes, which were thus not included in the evaluation). The shape files depict route paths as determined from the physical (paper copy) maps used by BBS observers when conducting their surveys. In general, BBS observers do not use GPS devices to follow a route. Thus, slight discrepancies may exist between a digitized route path and the actual route driven by an observer.

For each of the 2,696 digitized route paths, we used ArcGIS 10.2 to establish buffers at 0.4 km, 2 km, 5 km, and

TABLE 1. Local representativeness of the 400 m survey zones of Breeding Bird Survey routes for each cover type from the 2011 version of the National Land Cover Database. Intercept, slope, and r^2 values are from regressions of percent cover in 400 m zones vs. the 10 km landscapes surrounding each route ($n = 2,696$ routes). Standard errors for the intercept and slope are in parentheses.

Cover type [a]	Description [b]	Intercept	Slope	r^2
Developed–open space	Urban parks and recreational fields (IS <20%)	2.87 (0.079)	1.01 (0.016)	0.61
Developed–low intensity	Residential (IS 20–49%)	0.58 (0.043)	1.07 (0.014)	0.69
Developed–medium intensity	Residential and commercial (IS 50–79%)	0.11 (0.023)	0.92 (0.015)	0.59
Developed–high intensity	Residential, commercial, industrial (IS 80–100%)	0.02 (0.013)	0.78 (0.024)	0.28
Deciduous forest	Tree height >5 m and canopy cover >20%	0.02 (0.129)	0.85 (0.005)	0.92
Evergreen forest	As above, ≥75% of trees are evergreen	−0.37 (0.143)	0.93 (0.006)	0.89
Mixed forest	As above, deciduous and evergreen both <75%	−0.04 (0.039)	0.97 (0.006)	0.92
Shrub-scrub	Shrub height <5 m, canopy cover >20% but no overlap	−0.15 (0.149)	0.97 (0.004)	0.93
Barren Land	Natural or anthropogenic rock/sand surface, vegetation <15%	−0.004 (0.028)	0.66 (0.009)	0.64
Grassland/herbaceous	Grassy vegetation >80% and primarily natural	0.40 (0.110)	0.96 (0.005)	0.93
Pasture/hay	Grassy vegetation intentionally planted/managed for grazing	0.99 (0.118)	1.18 (0.009)	0.87
Cultivated cropland	Row or cover crops, including orchards and vineyards	1.13 (0.146)	1.05 (0.005)	0.94
Open water	Open water with <25% surface vegetation	0.55 (0.052)	0.21 (0.007)	0.24
Woody wetland	Water with >20% emergent woody vegetation	0.28 (0.079)	0.78 (0.008)	0.81
Herbaceous wetland	Water with >20% emergent grassy vegetation	0.01 (0.044)	0.84 (0.009)	0.75

[a] The "perennial ice/snow" category was not included in the assessment because it is almost nonexistent along BBS routes.
[b] "IS" refers to impervious surface (e.g., concrete, asphalt, other types of pavement); this is the main characteristic distinguishing the different levels of developed land.

10 km extents. For each route, the larger buffers were inclusive of the land area within each of the smaller buffers. Within each of these buffers for each route, we determined the percent cover of 15 different broad land cover types (Table 1) represented in NLCD 2011 (http://www.mrlc.gov/nlcd11_leg.php) (Homer et al. 2015). Given the 30 m resolution of the NLCD data, the average number of 900 m^2 pixels in a 0.4 km buffer running the entire length of a typical 39.2 km BBS route is ~37,000 (the value varies, depending on the shape of the route path and whether it is discontinuous). This level of resolution was more than sufficient for getting accurate estimates of percent cover of each land cover type. The 0.4 km buffers were considered as the nominal (de facto) area acoustically and visually surveyed by observers (Robbins et al. 1986); hence, all comparison (see below) is between the 0.4 km buffers and the larger buffers as in Niemuth et al. (2007) and Veech et al. (2012). A detailed description of the ArcGIS processing steps is given in Appendix A. The NLCD is one of the most extensive, high-resolution databases available. However, as with all land cover databases, users should be aware of the limitations of the data. Veech et al. (2012) discussed these limitations in the context of assessing representativeness of BBS routes. For further information, readers should also consult Thogmartin et al. (2004) and Gallant (2009).

Assessment of Route Representativeness

We assessed route representativeness per individual route (across cover types found along the route) and per cover type (among all routes having a particular cover type). For each route, we calculated the mean absolute difference (MAD) as compiled over all the cover types (n) present within either the 0.4 km or 10 km buffers, $\text{MAD} = (\Sigma|X_{i,0.4\text{km}} - X_{i,10\text{km}}|)/n$, where X_i = percent cover type 1 to n and summation is over all n. MAD was also obtained for each 0.4 km buffer compared to 2 km and 5 km buffers. For each individual route, values of MAD near zero indicate more accurate representation over all cover types on a route. For each cover type, our assessment involved performing linear regressions of the percent cover of the given cover type within the 0.4 km buffers (y) vs. percent cover within the larger buffers (x), 2 km, 5 km, and 10 km. The regressions were conducted separately for each cover type and each buffer size. From each regression, we obtained the intercept, slope (regression coefficient), and r^2 value. Together, these parameters indicate how well the land cover composition within the 0.4 km buffers represents land cover composition at the larger spatial extents (Veech et al. 2012). Increasingly better representation is indicated by intercept ~0, slope ~1, and r^2 ~1. Values of intercept <0 and slope <1 indicate that the cover type is underrepresented in the 0.4 km buffers, whereas intercept >0 and slope >1 indicate overrepresentation, when compared to larger buffers. We also assessed cover type representativeness by examining the distributions of $X_{0.4\text{km}} - X_{10\text{km}}$ values. These methods of assessing representativeness of BBS routes pertain to an entire set of routes (e.g., the set of 2,696 included in the present study), not to individual routes. This assessment was intended to identify cover types that might be overrepresented or underrepresented on routes. We note that our assessment is focused only on local representativeness as distinguished from regional representativeness;

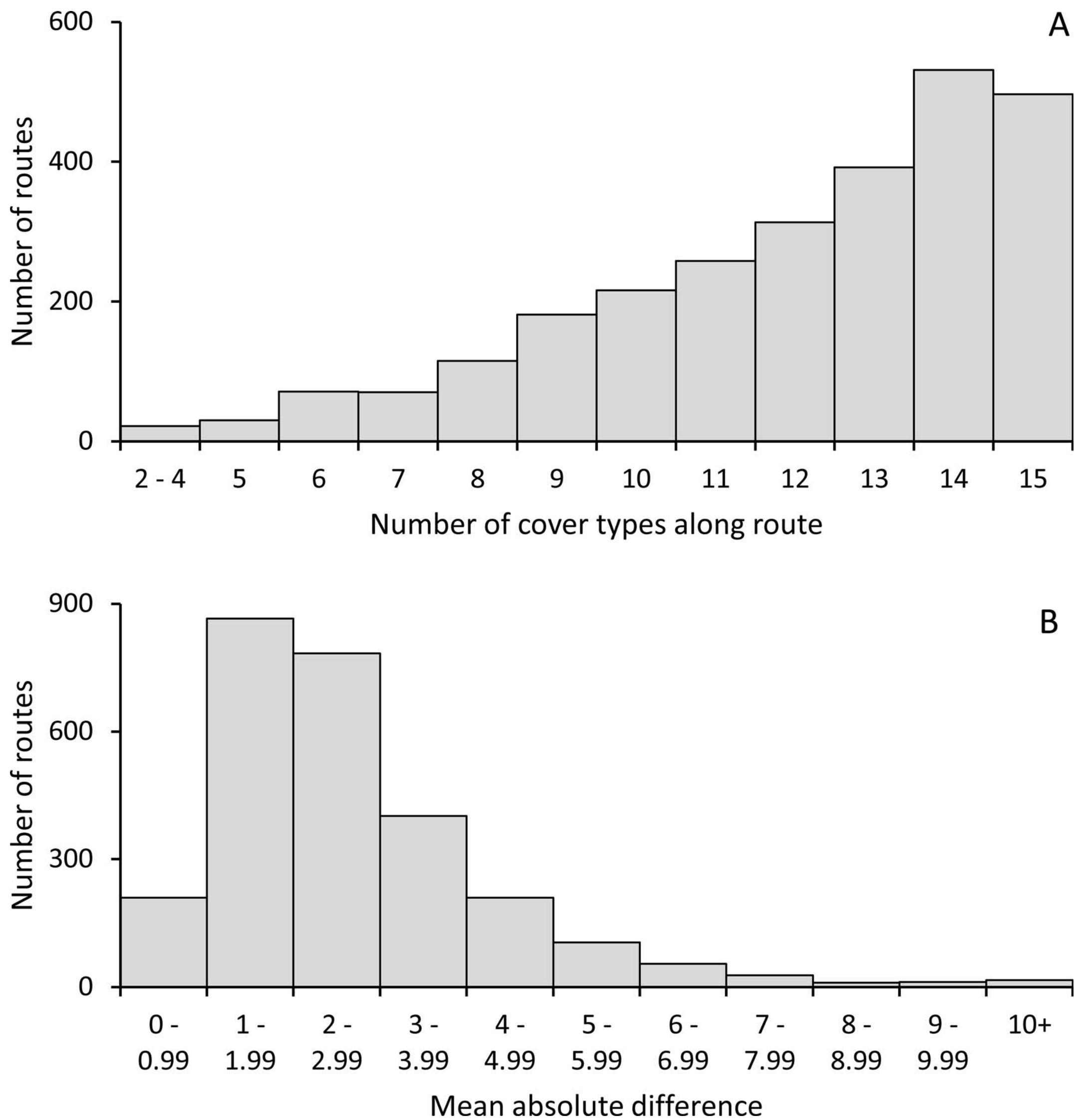

FIGURE 1. Number of routes of the North American Breeding Bird Survey with a given number of land cover types (from the 2011 version of the National Land Cover Database) in a 0.4 km buffer around digitized route path (**A**) and mean absolute difference (MAD) within a given range (**B**). MAD is compiled over all the cover types present within the 0.4 km buffer of a route. It represents the combined difference in land cover composition between the 0.4 km buffer and 10 km buffer of a route.

the latter entails examining the similarity in land cover composition between a collective set of routes and an entire region (Veech et al. 2012).

RESULTS

Most of the BBS routes (2,207 or 82%) had $\geq$10 NLCD land cover types within their 0.4 km buffers (Figure 1A). For most routes (2,470 or 92%), MAD was between 0 and 5 percentage points (pp; Figure 1B). Thus, for these routes, the 0.4 km buffers were different from the 10 km buffers by only $\leq$5 pp per land cover type. There were only 16 routes with MAD $>$10 pp, and the highest MAD value was 22.1 pp. The grand mean MAD over all routes was 2.68 pp, and the median was 2.27 pp. Examining individual cover types between 0.4 km and 10 km (Figure 2), only developed–medium intensity (3), grassland (10), and cropland (12) had relatively equal numbers of routes showing positive $X_{0.4\text{km}} - X_{10\text{km}}$ values and negative $X_{0.4\text{km}} - X_{10\text{km}}$ values (numeric values next to land cover labels correspond to coding in figures). Cover types in which most routes had $X_{0.4\text{km}} > X_{10\text{km}}$ included developed–open space (1), developed–low intensity (2), and pasture/hay (11); the remaining cover types (including all forest and aquatic types) had $X_{0.4\text{km}} < X_{10\text{km}}$ for the majority of routes. The statistical distribution of $X_{0.4\text{km}} - X_{10\text{km}}$ values was also

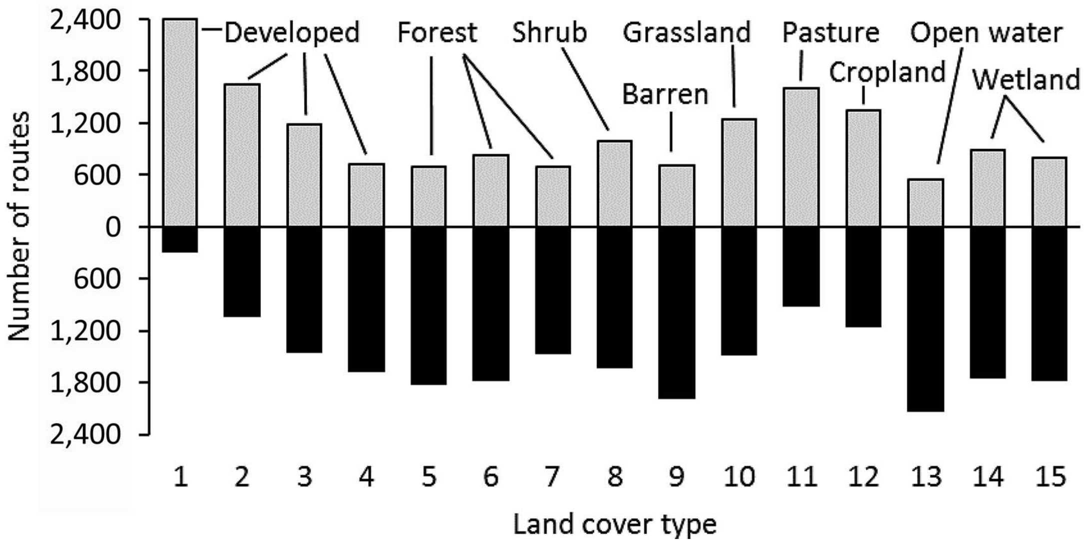

FIGURE 2. Comparison of percent cover of land cover types within the 0.4 km buffers and the 10 km buffers along routes of the North American Breeding Bird Survey. Number of routes in which the difference in percent cover of the given land cover type ($X_{0.4km} - X_{10km}$) was either positive (gray bars) or negative (black bars). Cover type labels are as follows: 1 = developed–open space, 2 = developed–low intensity, 3 = developed–medium intensity, 4 = developed–high intensity, 5 = deciduous forest, 6 = evergreen forest, 7 = mixed forest, 8 = shrub-scrub, 9 = barren, 10 = grassland, 11 = pasture/hay, 12 = cropland, 13 = open water, 14 = woody wetland, and 15 = herbaceous wetland. Land cover categories are from the 2011 version of the National Land Cover Database.

informative in showing that developed–open space (1), developed–low intensity (2), pasture/hay (11), and cropland (12) tended to occur at a higher percentage within the 0.4 km buffers than in the 10 km buffers, whereas the opposite pattern was found for deciduous forest (5), evergreen forest (6), open water (13), and woody wetland (14) (Figure 3).

The regression of percent cover in the 0.4 km buffers vs. 10 km buffers indicated that most cover types were represented in the smaller buffers in a roughly similar proportion as in the larger buffers, as indicated by the clustering of data points along the line of unity ($X_{0.4km} = X_{10km}$) in scatter plots (Figure 4). Possible exceptions were developed open space, which had the highest intercept (2.87); otherwise, the intercepts for all other cover types were between –0.37 and 1.13 (Table 1). Values close to zero indicate that the percent cover (of the given cover type) in the 0.4 km buffers represents well the land cover in the larger surrounding buffers. Slope values were all relatively close to 1.0 (between 0.66 and 1.18), again indicating good representation, except for open water (0.21), which also had a very low r^2 value (0.24) (Table 1). The regression analysis revealed that deciduous forest, mixed forest, and shrub-scrub were the cover types most accurately represented in the 0.4 km buffers, as indicated by an intercept $\approx$0 and slope $\approx$1 (Table 1). As expected, the 0.4 km buffers became less representative of larger landscapes as the size or spatial extent of those larger landscapes increased (Figure 5).

DISCUSSION

Our assessment using NLCD 2011 data revealed that the roadside areas immediately adjacent to BBS routes (survey paths along roads and highways) are generally representative of larger surrounding landscapes. More precisely, the 400 m radius areas surveyed by BBS observers during each of 50 "stops" along a route have a land cover composition that is similar to that occurring at a much greater spatial extent. With only a few exceptions (see below), there is no roadside bias in the form of certain land cover types being either more or less common within the survey areas than in the larger surrounding landscapes. This reaffirms the soundness of the BBS sampling design. Moreover, roughly similar assessments that have been performed previously with other land cover data found BBS routes to be generally representative of larger landscapes, although with 1 or 2 cover types typically overrepresented or underrepresented (Keller and Scallan 1999, Lawler and O'Connor 2004, Betts et al. 2007, Niemuth et al. 2007, Veech et al. 2012, Van Wilgenburg et al. 2015). Not surprisingly, our results affirm that the roadside landscape becomes a less predictable representation of the larger landscape as buffer width increases (Figure 5).

In the previous assessment using the same analytical methods but applied to NLCD 2001 data and a greater set of routes ($N = 3{,}230$), Veech et al. (2012) found levels of representativeness similar to those revealed in the present study. Comparison of Table 1 to Veech et al. (2012: table 2) shows that the intercept, slope, and r^2 values from

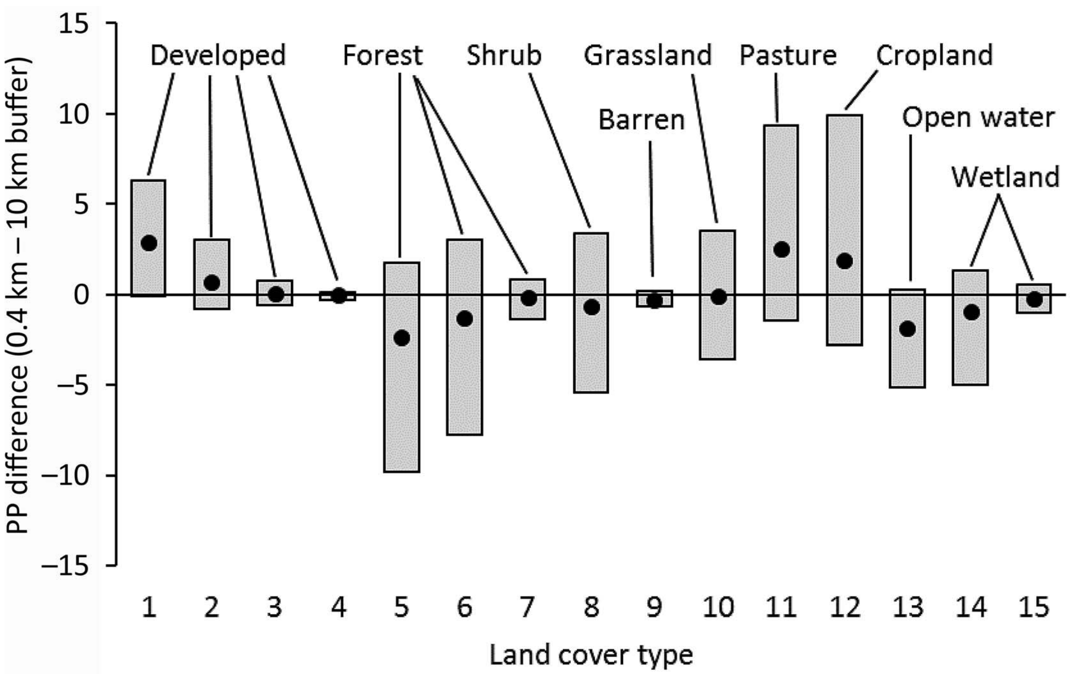

FIGURE 3. Distribution of the percentage-point (PP) differences between the percent cover in 0.4 km buffers ($X_{0.4km}$) and 10 km buffers (X_{10km}) along routes of the North American Breeding Bird Survey for each of 15 land cover categories. Tops of bars represent the 90th percentile, and bottoms represent the 10th percentile; thus, each bar includes the middle 80% of routes ($n = 2{,}157$). Black dot represents the mean. Land cover categories are from the 2011 version of the National Land Cover Database, with numeric labeling as in Figure 2.

regressions of percent cover in the 400 m survey areas vs. the 10 km buffers were very similar between 2001 and 2011, even though the 2001 assessment included a greater number of routes. For most cover types, slope and r^2 values are >90% similar when using either NLCD 2001 or 2011 data. The difference in intercept values is between –0.29 and 0.55 for all cover types. The slight discrepancy between the results of Veech et al. (2012) and the present results could be because the set of routes was not the same in the 2 analyses. Even given the different route sets, comparison of the present assessment to Veech et al. (2012) indicates that the overall representativeness of BBS routes did not change between 2001 and 2011. However, note that the comparison of representativeness between 2001 and 2011 is not a direct assessment of the representativeness of *temporal* change in land cover along the routes. The latter requires examination of NLCD data indicating the land cover conversions occurring between 2001 and 2011 in each pixel.

In the present assessment, open water is the only cover type that is unequivocally underrepresented in the 400 m survey areas along BBS routes. This is not surprising. Except in the case of bridges, roads do not traverse waterways. In some situations, roads and highways may roughly follow the shoreline of a large body of water or a river, but perhaps not very often within 400 m of the water, and not for the entire perimeter of the water body. For smaller water bodies, roads likely dead-end at the water body, providing single-point access instead of continuous access along the shoreline. Either situation leads to less water close to the road compared to the amount of surface water in a landscape extending a few kilometers or more from the road.

Developed–open space and, to a lesser extent, cropland and pasture/hay tend to be overrepresented in the 400 m survey areas. Again, this is not surprising, given that these are all anthropogenic cover types. Anthropogenic modification of landscapes is expected to be greater along roadsides than at distances farther from roads. Developed–high intensity is the most anthropogenic cover type. Unlike developed–open space, it may be underrepresented in the 400 m survey areas (slope = 0.78; Table 1). However, developed–high intensity is a very minor component of the 400 m survey areas (average = 0.17%) and larger 10 km landscapes (average = 0.19%). Similarly, developed–medium intensity (means = 0.69% and 0.65%) and barren land (means = 0.51% and 0.78%) are also very minor components. For these uncommon cover types, it is difficult to assess representativeness. Nonetheless, the overall low percentage of developed (urbanized) land in the 400 m survey areas is likely due to safety concerns and to BBS routes not traversing highly urbanized areas

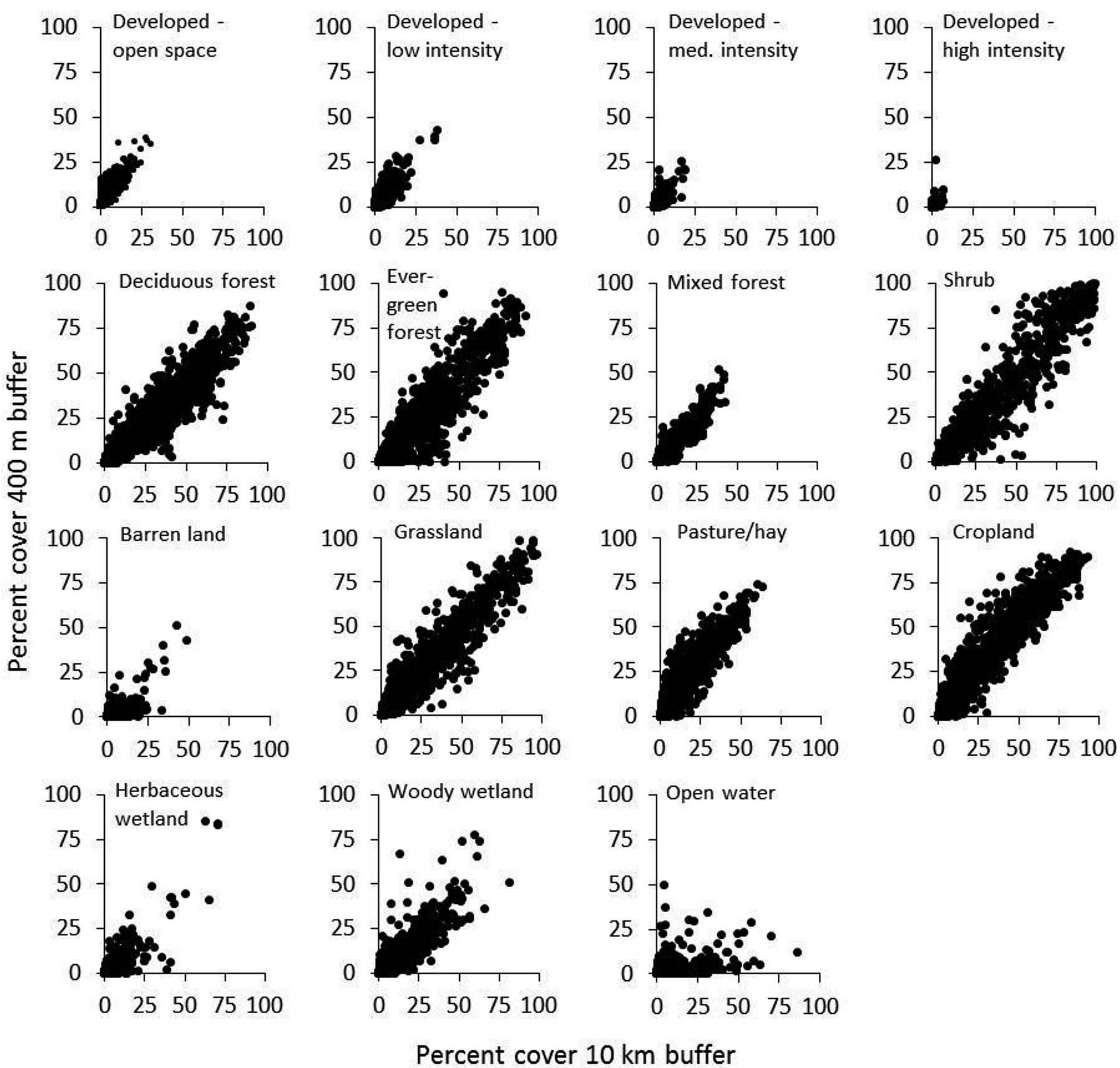

FIGURE 4. Plots of percent cover in the 0.4 km buffer zones vs. 10 km landscapes (buffers) surrounding routes of the North American Breeding Bird Survey ($n = 2{,}696$ routes) for each of the 15 land cover categories from the 2011 version of the National Land Cover Database.

because traffic and noise interfere with the acoustic and visual survey process.

The "natural" land cover types (forest, shrub, grassland, woody wetland, and grassy wetland) tended to be accurately represented in the 400 m survey areas as indicated by the regression assessment; intercepts were relatively close to zero, and slopes were very close to 1. However, for all these natural cover types except grassland, there were substantially more routes where the cover type was underrepresented in the 400 m survey areas (as compared to 10 km buffers) rather than overrepresented (Figure 2), and the statistical distributions of percentage-point differences (Figure 3) reflected this bias toward underrepresentation. Nonetheless, mean values of the percentage-point differences were always between –3 and 3; this indicates that as a collective group the 2,696 routes had representative percentages of natural land cover within their 400 m survey areas. To be clear, our assessment focused on the representativeness of BBS routes as a collective group. We did not assess the representativeness of individual routes.

We also did not examine whether the amount of land cover fragmentation along BBS routes is similar to that in the larger surrounding landscape. For most cover types,

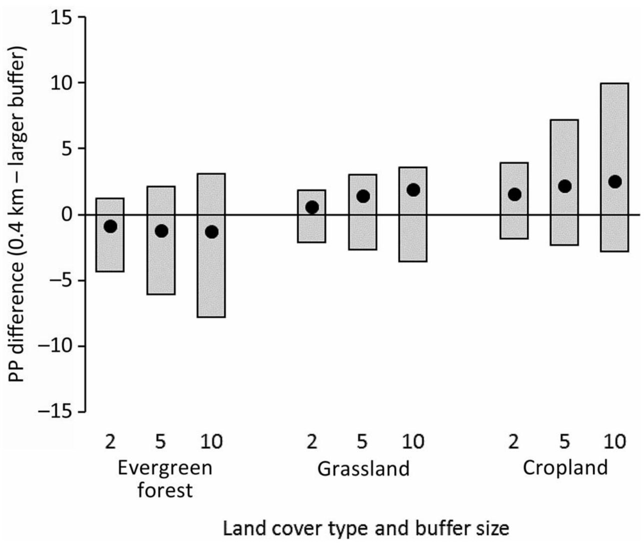

FIGURE 5. Effect of spatial extent on representativeness of 0.4 km buffers along routes of the North American Breeding Bird Survey. For each of 3 select land cover types, comparison is made between 0.4 km buffers and buffers at 2 km, 5 km, and 10 km, shown as a percentage-point (PP) difference. As in Figure 3, bars represent values between the 10th and 90th percentiles and black dots represent means. Land cover categories are from the 2011 version of the National Land Cover Database.

the amount of fragmentation is similar in route survey areas compared to landscapes within 2 km of the road, although fragmentation does decrease with greater distance (e.g., 10 km) from the road (J. A. Veech personal observation). Given that the size and spatial configuration of habitat patches can affect some bird species, a formal analysis of landscape fragmentation can be important for some studies utilizing BBS data (Gutzwiller et al. 2015).

Finally, the most important (albeit unaddressed) question is whether land cover representativeness translates into bird representativeness. Even if habitat (or more generally land cover composition) is exactly identical in the 400 m survey areas and larger surrounding landscapes, the bird fauna available to be counted during the survey may be different from that existing farther from the road. Previous studies have examined such a roadside effect or bias and found mixed results (Hanowski and Niemi 1995, Sutter et al. 2000, Dieni and Scherr 2004, Wellicome et al. 2014). A roadside effect will exist if there are certain bird species attracted to features (e.g., utility wires or fences for perching) or food resources (e.g., grain bins and livestock feed lots) along the road or if certain species are repelled by roads, such as those species with a strong aversion to human activity and disruption. Indeed, several studies have documented lower bird species richness and abundance near roads (Summers et al. 2011 and references within), while other studies have shown roadside estimates to be appropriate for larger landscapes (Lituma and Buehler 2016). Although traffic noise inevitably decreases detection, in the absence of traffic noise, forest birds can be easier to detect along roadsides (Yip et al. 2017). Our study was not intended to assess these roadside biases. However, our results suggest that any roadside bias due to habitat is likely very minimal because habitat and land cover composition along most routes is similar to that of the surrounding landscape. Given that BBS route survey areas have representative land cover, a possible next step is to begin using land cover data (perhaps NLCD or another database) more explicitly in the estimation of bird population trend. Of course, this task would need to be initiated cautiously, keeping in mind the limitations of land cover data and our incomplete understanding of how land cover categories correspond to habitats used by birds.

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APPENDIX A

GIS Processing of NLCD Land Cover Data

NLCD raster files were obtained from http://www.mrlc.gov/nlcd01_data.php. There have been several versions or "releases" of NLCD data (1992, 2001, 2006, and 2011); we used the most recent, NLCD 2011. The nominal dates of an NLCD release (e.g., 2001, 2006, 2011) do not correspond exactly to the year of the imagery. Typically, the imagery used in a particular release is from 1 or 2 yr previous to the nominal year of the release; image processing and interpretation requires up to 2 yr from the date the images are obtained. GIS processing was carried out using ArcGIS 10.2 and IDLE (a Python user interface) in 3 main steps. (1) A customized geoprocessing model in ArcMap was used to iterate through all BBS routes to create 0.4 km, 2 km, 5 km, and 10 km nested (inclusive) buffers for each route. Some of the routes consisted of multiple line segments (when digitized as a feature); hence, there was some overlap at the end of the buffered segments. This unwanted overlap was removed by using the ArcGIS "Dissolve" tool. (2) ArcPy script (computer code) was then applied to the shape files of the buffered routes, which were used as the clip features to extract individual BBS route raster files representing the NLCD 2011 data layer for that route. This step produced one raster file per route and thus avoided the "cookie cutter" error that occurs when ArcGIS sequentially processes features (e.g., BBS routes) with overlapping buffers stored in the same file. (3) The "Tabulate Area" tool was then applied to each separate raster file to get pixel counts of each land cover category within the buffer; these pixel counts were then converted to percent cover.