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REPRESENTATIVENESS OF LAND COVER COMPOSITION ALONG ROUTES OF THE NORTH AMERICAN BREEDING BIRD SURVEY

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Abstract.—The North American Breeding Bird Survey (BBS) is an annual transect point-count survey of >500 species and >3,500 survey routes (transects). Observers drive and record birds seen and heard within a radius of 400 m of 50 survey points ("stops") evenly spaced along a 39.4-km survey route. Thus, the land area along both sides of a route composes a linear or curvilinear landscape. Although BBS data have been used in many studies and conservation plans, there have been few attempts to determine how well the landscapes along BBS routes represent landscapes at larger spatial extents, particularly with regard to land-cover composition. Using data from the 2001 National Land Cover Database, we conducted a study of representativeness of 3,230 routes by comparing the differences in percent cover of 15 land-cover types in BBS landscapes (buffer width of 0.4 km surrounding a route) to larger local landscapes (10 km buffer width) and regions. At the local level, BBS landscapes were representative for most of the cover types except open water, which was underrepresented, and lightly developed open space, which was overrepresented. At the regional level, the collective composition of BBS landscapes was very similar to the composition within entire Bird Conservation Regions. Overall, these results should encourage the continued use of BBS data in ornithological and ecological research and in conservation planning. *Received 3 March 2011, accepted 19 February 2012.*

Key words: conservation planning, GIS, habitat, landscape composition, remote sensing, route representativeness.

Representatividad de la composición de la cobertura terrestre a lo largo de las rutas del Censo de Aves Reproductivas de Norte América

Resumen.—El Censo de Aves Reproductivas de Norte América (BBS, por sus siglas en inglés) es un censo anual basado en puntos de conteo de >500 especies y >3500 rutas de muestreo (transectos). Los observadores conducen y registran las aves vistas y escuchadas dentro de un radio de 400 m en 50 puntos de muestreo ("paradas") espaciados equitativamente a lo largo de una ruta de censo de 39.4 km. De esta manera, el área de tierra a lo largo de los dos extremos de una ruta produce un paisaje lineal o curvilíneo. Aunque los datos del BBS han sido usados en muchos estudios y planes de conservación, ha habido pocos esfuerzos por determinar en qué medida los paisajes a lo largo de las rutas del BBS representan los paisajes de escalas espaciales mayores, particularmente en lo que concierne a la composición de la cobertura terrestre. Usando datos de la National Land Cover Database de 2001, hicimos un estudio de la representatividad de 3230 rutas al comparar las diferencias en el porcentaje de cobertura de 15 tipos de cobertura terrestre en los paisajes del BBS (ancho de amortiguación de 0.4 km alrededor de una ruta) contra paisajes locales más grandes (amortiguación de 10 km) y paisajes regionales. En el nivel local, los paisajes del BBS fueron representativos de muchos de los tipos de cobertura, excepto de aguas abiertas (que estuvieron poco representadas) y de espacios abiertos poco desarrollados (que estuvieron sobre representados). Al nivel regional, la composición colectiva de los paisajes del BBS fue muy similar a la composición dentro de la totalidad de las Regiones de Conservación de Aves. En general, estos resultados deberían fomentar el uso continuo de los datos del BBS en la investigación ecológica y ornitológica, y en la planeación para la conservación.

The North American Breeding Bird Survey (BBS) is an unprecedented database of information on abundance and distribution of >500 bird species. Few surveys for vertebrates rival the BBS in spatial coverage and temporal duration. The BBS consists of >3,500 survey routes distributed throughout the United States and parts of Canada and Mexico. It is an ongoing survey, conducted annually, since 1966. Compared to other bird surveys (e.g., Christmas Bird Count, eBird), the BBS has the most standardized protocol for data collection (Sauer and Droege 1990). All data are collected by observers driving secondary roads and highways for a set distance (i.e., route length is constant at 39.4 km), stopping every 800 m to record birds seen and heard during a 3-min observation period (Sauer et al. 1994). Given the magnitude and design of the BBS, it has been and will continue to be an important tool in conservation assessment and planning.

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Use of BBS data is central to the North American Landbird Conservation Plan developed by Partners in Flight and the North American Bird Conservation Initiative. The plan uses BBS data to derive current population estimates and to develop conservation strategies for hundreds of species within Bird Conservation Regions (BCRs; Rich et al. 2004, Rosenberg and Blancher 2005, Thogmartin et al. 2006). Breeding Bird Survey data have also been used in smaller-scale conservation assessments and analyses (Boren et al. 1999, Rodríguez 2002, Krueper et al. 2003, Vance et al. 2003, Thogmartin et al. 2004b, Coppedge et al. 2006, Forcey et al. 2007, Herkert 2007, Riffell et al. 2008). Many of these studies attempt to relate population size and temporal trend to habitat composition within landscapes surrounding BBS routes (Blackwell and Dolbeer 2001; Vance et al. 2003; Thogmartin et al. 2004b; Veech 2006a, b; Herkert 2007; Riffell et al. 2008). However, a crucial and sometimes overlooked aspect of these studies and conservation plans is whether BBS landscapes (i.e., the strip of land a few hundred meters wide surrounding a BBS route) accurately represent landscapes at much larger spatial extents with respect to land-cover composition. We refer to this concept as the "representativeness" of a BBS route. Representativeness can be assessed locally, by comparing individual BBS landscapes to larger landscapes that they are embedded within; and regionally, by comparing a collective group of BBS landscapes to the larger region that contains them.

During the early development of the BBS, survey routes were located "randomly" within 1° latitude–longitude blocks, with 1 to 8 routes per block (Sauer and Droege 1990, Sauer et al. 2003). However, placement of routes has never been completely random, given that routes are confined to secondary highways and that routes are more likely to have been established (1) in regions with a high density of volunteer observers (Sauer and Droege 1990) and (2) to avoid crossing the boundaries of regions (initially, "Bystrak strata" and now BCRs; Sauer et al. 2003). Given these limitations on truly random placement, a pervasive concern has always been whether BBS routes adequately represent the environmental conditions and land-cover composition within a greater encompassing area (e.g., from landscapes of 100s to 1,000s km^2 to much larger regions).

Despite increased availability of geographic information system (GIS) technology, remote sensing, and aerial imagery data in the past decade, few studies have examined the representativeness of BBS landscapes (Bart et al. 1995, Keller and Scallan 1999, Lawler and O'Connor 2004, Niemuth et al. 2007). Moreover, these studies were limited in geographic scope, evaluated fewer BBS routes than the present study, and did not thoroughly analyze land-cover composition. The use of BBS data in conservation assessment and planning can be greatly increased and improved with knowledge of how well landscapes along BBS routes represent landscapes at much larger spatial extents. The need for this knowledge has been recognized previously (Carter et al. 2000, O'Connor et al. 2000, Ruth et al. 2003); more specifically, our study accomplishes high-priority Objective 1B2b of the Strategic Plan for the North American Breeding Bird Survey: 2006–2010, which states: "Evaluate the magnitude of potential bias associated with non-random coverage of habitats, considering differences in habitat availability and habitat change along BBS routes compared with the broader landscape" (U.S. Geological Survey 2007). For our study, high or "good" representativeness means that a BBS landscape is comparable to the broader landscape in land-cover composition. Here, we present a study that quantifies local and regional representativeness of BBS landscapes throughout the conterminous United States.

Methods

Land-cover data.—We used ARCGIS, version 9.2 (ESRI, Redlands, California), to determine proportions of 15 land-cover types in landscapes surrounding each of 3,230 active BBS routes distributed throughout the 48 conterminous states of the United States. Routes in Canada and Mexico were not analyzed because we did not have land-cover data for those routes. At the smallest extent, we used a buffer distance of 0.4 km to delimit the landscape; that is, the landscape consisted of the entire area on both sides of the survey route to a distance of 400 m (Niemuth et al. 2007). According to BBS survey protocol, 400 m is the maximum distance at which a stationary observer can visually and acoustically record presence of birds during a 3-minute period (Robbins et al. 1986; Sauer et al. 1994, 2008).

For assessment of local representativeness, we delimited the larger landscape on the basis of a 10-km buffer. This corresponded to the smaller 0.4-km landscapes being about 3–4% the size of the 10-km landscapes. We also examined 1-, 2-, 3-, 5-, 7-, and 50-km buffer increments for a subset of routes to evaluate whether local representativeness was affected by the size of the larger landscape. For assessment of regional representativeness, we used the BCRs outlined by the North American Bird Conservation Initiative for conservation planning and monitoring (U.S. NABCI Committee 2000, Sauer et al. 2003). A BCR is defined as having similar land-cover composition, climate, geology, and bird assemblages throughout its area, particularly in comparison to other BCRs. There are 30 BCRs partially or entirely within the conterminous United States (Fig. 1). By design, our assessment of representativeness did not test whether the 0.4-km landscapes are a random subset of all possible 0.4-km landscapes within a BCR or any other region; our goal was not to test for a random spatial distribution of BBS routes but, rather, to test whether BBS routes are representative given their distribution.

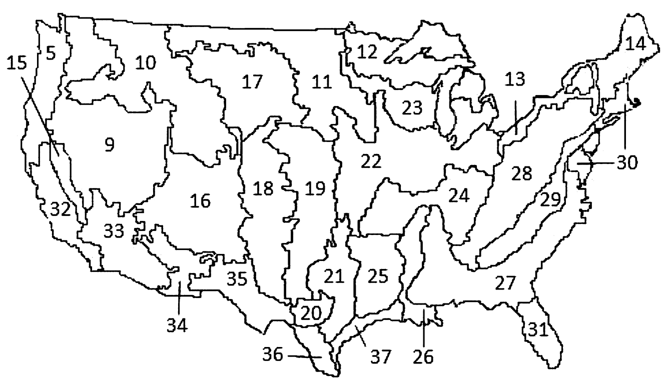

Fig. 1. Bird Conservation Regions (BCRs) within the conterminous United States. Number labels were assigned by the North American Bird Conservation Initiative. Descriptions of each BCR and a detailed map are available at www.nabci-us.org/map.html.

We obtained land-cover data from the 2001 National Land Cover Database (hereafter "NLCD 2001"; Homer et al. 2007, Wickham et al. 2010), which includes 29 different land-cover types. Because many of these cover types occur only in Alaska or coastal areas, we analyzed 15 major cover types (Table 1). Most of the NLCD 2001 data were derived from Landsat 5 and 7 satellite imagery taken during 2001 (Homer et al. 2004, 2007) and are available at 30-m resolution. We accessed NLCD 2001 data through the Multi-Resolution Land Characteristics Consortium seamless viewer, and a shapefile of all BBS routes was downloaded from the National Atlas (see Acknowledgments). Buffers were then created around each route. To quantify cover types within the buffers (landscapes), we used the thematic raster summary in the Hawths Tools extension for ARCGIS (see Acknowledgments). We also obtained shape files for each BCR and again used ARCGIS to derive the NLCD land-cover estimates within each BCR.

Evaluating representativeness of BBS landscapes.—For local representativeness, we compared BBS landscapes (i.e., 0.4-km buffer distances) with larger landscapes by regressing percent cover in 0.4-km landscapes ($P_{0.4,i,j}$) against that in 10-km landscapes ($P_{10,i,j}$) for each cover type (i) separately using all j = 1 to 3,230 BBS routes. The regression equations were $y = mx + b$, where $y = P_{0.4,i,j}$, $x = P_{10,i,j}$, m = the slope, and b = y-intercept. The y-intercept from the regression equation represents a constant amount of "error" in the 0.4-km landscapes, whereas the slope represents an amount of error proportional to the percentage of a given cover type in the 10-km landscapes. Here, we are using the word "error" loosely to mean a mismatch between the smaller and larger landscapes. Regression allowed us to estimate the two sources of error (constant and proportional) that might lead to non-representativeness. In this regression approach, perfect representativeness would have $b = 0$ and $m = 1$ (no constant or proportional error).

We also assessed representativeness on the basis of differences between the 0.4-km and 10-km landscapes. For each cover type and route, we calculated $P_{0.4,i,j} - P_{10,i,j}$ and then obtained the mean of the positive values and a separate mean for the negative values. Essentially, these are the "residuals" for a regression where $b = 0$ and $m = 1$. Small mean values of $P_{0.4,i,j} - P_{10,i,j}$ indicate greater representativeness. Additionally, a positive mean equal to the negative mean indicates a lack of directional bias in representativeness (or non-representativeness), regardless of magnitude. Note that the difference, $P_{0.4,i,j} - P_{10,i,j}$, is a percentage point difference, not a percent difference. A small percentage point difference (e.g., 6% − 3% = 3%) may sometimes represent a large percent difference (e.g., 100%) when the raw percentages are small. Here, we mostly present and interpret results as percentage point differences because a given percentage point difference represents the same amount of land regardless of whether the raw percentages are large or small. For example, both 20% − 16% and 8% − 4% represent a percentage point difference of 4, but they represent percent differences 25% and 100%, respectively.

To evaluate regional representativeness, we compared the percent cover in the combined 0.4-km landscapes of a BCR ($P_{comb,i}$) to the cover within the total area of the BCR ($P_{BCR,i}$), for all i = 1 to 15 NLCD cover types. To aid in this comparison, we calculated several summary statistics, such as mean absolute difference of $P_{comb,i} - P_{BCR,i}$, maximum positive and maximum negative

Table 1. The 15 land-cover types of the 2001 National Land Cover Database (NLCD) used in the present study.

Name (NLCD code)	Description	Mean cover [a]
Developed Open Space (21)	Town and city parks, recreational fields, large-lot neighborhoods (impervious surface <20% of total cover)	6.59, 3.46
Developed Low Intensity (22)	Neighborhoods (impervious surface 20–49%)	2.39, 1.51
Developed Medium Intensity (23)	Neighborhoods (impervious surface 50–79%)	0.64, 0.55
Developed High Intensity (24)	High-density residential, commercial, industrial (impervious surface 80–100%)	0.17, 0.17
Deciduous Forest (41)	Trees >5 m height, canopy cover >20%, 75% of trees are deciduous	14.53, 16.83
Evergreen Forest (42)	As above but 75% of trees are evergreen	12.75, 14.08
Mixed Forest (43)	As above but neither deciduous or evergreen >75%	3.06, 3.19
Shrub/Scrub (52)	Shrubs <5 m height, canopy cover >20% but little canopy overlap	15.70, 16.23
Barren Land (31)	Natural or anthropogenic rock–sand surface, vegetation <15%	0.66, 0.90
Grassland/Herbaceous (71)	Grass or herbaceous vegetation >80%, all natural or seminatural mix of species, little or no management	10.96, 10.78
Pasture/Hay (81)	Grass or legume species planted and managed for grazing, >20% of total vegetation	10.37, 8.21
Cultivated Cropland (82)	Annual row or cover crops, including orchards and vineyards, actively tilled land, >20% total vegetation	16.05, 14.82
Open Water (11)	Open water with <25% soil or vegetation cover	1.16, 3.09
Woody Wetland (90)	Woody vegetation >20% total vegetation, substrate covered with water permanently or typically	3.76, 4.36
Herbaceous Wetland (95)	As above but with grass	1.22, 1.36

[a]Percent cover shown as a mean over all 3,230 Breeding Bird Survey route-landscapes at buffer widths of 0.4 km and 10 km, respectively.

differences. This assessment of regional representativeness examined whether the BBS route-landscapes within a BCR collectively represent land-cover composition throughout the BCR.

Results

Among all 3,230 route-landscapes, mean percent cover was greatest for the forest and shrub cover types and cropland, and lowest for medium- and high-intensity developed land and barren land (Table 1). Percent cover of different cover types varied considerably among the routes, as indicated by relatively high CVs from 60% to 400%. Developed land (open space, low-, medium-, and high-intensity) and barren land varied the least and were also some of the least common cover types. For these, percent cover was almost always <25%, and typically <10%, in the 0.4-km and 10-km route-landscapes. Most other cover types ranged from 0% to near 100% within the landscapes (Fig. 2). These results illustrate the wide range of landscape composition among BBS routes.

Local representativeness.—For most cover types analyzed, there were only small absolute differences (<1.5 percentage points) between the mean percent cover within the 0.4-km and 10-km landscapes (Table 1), which indicates that the smaller landscapes were similar to the larger ones, except for a few cover types. The representativeness of BBS routes can also be seen in plots of percent cover in the 0.4-km vs. 10-km landscapes (Fig. 2). Clustering of points along the line of equality indicates greater representativeness. That is, points on or near the line are routes with very little difference in percent cover (of a given cover type) between 0.4-km and 10-km landscapes. For most cover types, except open water and developed land, there is clustering along the line of equality (Fig. 2). However, for every cover type, there are some routes in which the 0.4-km landscapes are not representative of the 10-km landscapes, as indicated by points far from the line of equality (e.g., 0.4-km and 10-km landscapes that differ by 10 percentage points or more).

A more thorough assessment of representativeness is obtained by examining the y-intercept and slope values from the regressions (Table 2). Except for open water (b = 3.23), all cover types had relatively small y-intercepts (b < 1.5 percentage points), indicating minimal constant error or mismatch between the smaller and larger landscapes (Table 2). In addition, most cover types had low amounts of proportional error, as indicated by slopes near 1.0 (Table 2); notable exceptions were developed high-intensity land (m = 0.52), barren land (m = 0.73), and open water (m = 0.22). The regressions for these cover types also had r^2 values that were generally lower than those of the other cover types (Table 2).

Representativeness was also assessed by the difference, $P_{0.4,i,j} - P_{10,i,j}$, as a mean over all 3,230 routes and for each cover type. As with the y-intercept and slope, the difference is expressed as percentage points. Mean differences (positive and negative) varied considerably among cover types, from 0.37 to 5.74 for positive differences and from –0.17 to –5.19 for negative differences (Table 2). The greatest differences tended to represent cover types that were more common (e.g., deciduous forest, evergreen forest, shrub, grassland, pasture, and cropland), and the smallest differences represented less common cover types (e.g., developed high-intensity land and barren land) (Tables 1 and 2). For most cover types, the mean positive difference was greater than the mean negative difference; this was particularly evident for developed open space, pasture, and cropland (Table 2). By constrast, open water had a mean negative difference (–2.84) greater than the mean positive difference (1.15).

Landscape size did not greatly affect our assessment of local representativeness, and therefore we do not present detailed results of that analysis. For each cover type, the amount of constant and proportional error either remained constant or increased only slightly with increasing landscape size (from 1-, 2-, 3-, 5-, 7-, to 10-km buffer widths). However, there was a substantial amount of error (non-representativeness) when the 0.4-km landscapes were compared with 50-km landscapes.

Regional representativeness.—The BCRs vary substantially in area (Fig. 1) and, thus, vary in number of BBS routes. In our study, the mean number of routes included per BCR ranged from 16 to 325, but total area sampled by the routes did not vary as much (Table 3). For most BCRs, the combined area of the 0.4-km route-landscapes was 0.65–2.19% of the total area of the BCR. There were only four BCRs (5, 26, 36, and 37) for which the mean absolute difference (mean over the 15 cover types) between the combined 0.4-km landscapes and the BCR was >2 percentage points but never >3 percentage points. Within a BCR, values of $P_{\text{comb},i} - P_{\text{BCR},i}$ were usually <5 percentage points (Table 3). There were several BCRs (5, 9, 26, and 36) for which the maximum negative value of $P_{\text{comb},i} - P_{\text{BCR},i}$ exceeded 10 percentage points. Maximum negative values typically represented deciduous forest (41), evergreen forest (42), shrubland (52), or grassland (71). There was only one BCR (37) where the maximum positive value of $P_{\text{comb},i} - P_{\text{BCR},i}$ was >10 percentage points (Table 3). Maximum positive values mostly represented developed low-intensity (cover type 21), pasture–hay (81), or cropland (82). Presumably, the number of routes in a BCR and the percent of BCR area (represented by the routes) could affect how well the routes represent land-cover composition within the BCR. However, neither of these variables had a significant positive correlation with mean absolute difference (r = –0.18 and 0.06, respectively).

The analysis of each cover type across BCRs revealed that the difference in percent cover between the 0.4-km landscapes and the BCR ($P_{\text{comb},i} - P_{\text{BCR},i}$) were typically between −4% and +4% (Fig. 3). A few cover types (e.g., evergreen forest, shrub, grassland, and cropland) had greater discrepancies (<–8% and >+8%) in some BCRs (Fig. 3 and Table 3). Also, developed open space was consistently (but only slightly) overrepresented in the BBS route-landscapes in all BCRs, and open water was underrepresented in the BBS route-landscapes for most BCRs (Fig. 3). The latter two results mirror those found during the analysis of local representativeness; developed open space and open water tend to be over- and under-representative, respectively, of the local 10-km landscapes as well.

Discussion

Local representativeness.—Our study revealed that for most of the NLCD 2001 land-cover types analyzed, landscapes immediately surrounding BBS routes are similar to landscapes at larger spatial extents. That is, the mean difference in percent cover between the 0.4-km and 10-km landscapes is typically <5 percentage points for most NLCD cover types. Also, for most cover types, the amount of constant and proportional error in percent cover values is reasonably low (Table 2), which suggests that there is no serious systematic bias in the cover estimates within the 0.4-km landscapes. These results

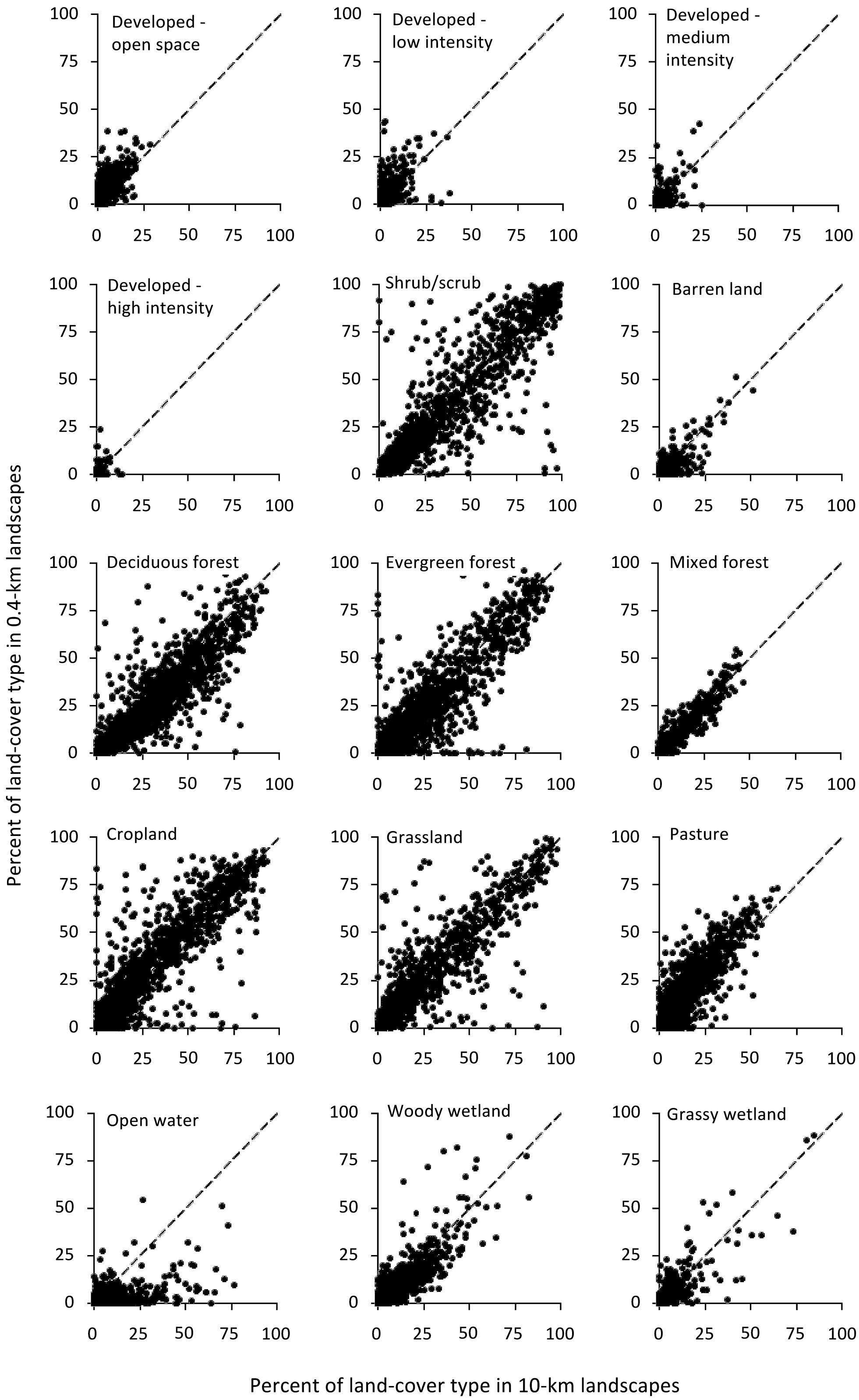

FIG. 2. Plots of percent cover in the 0.4-km vs. 10-km Breeding Bird Survey (BBS) route-landscapes for each land-cover type of the National Land Cover Database 2001. Dashed line is line of equality ($y = x$), not the actual least-squares regression line. Plots are based on all 3,230 BBS routes; each point represents a route-landscape.

TABLE 2. Local representativeness of the 0.4-km Breeding Bird Survey route-landscapes for each cover type of the National Land Cover Database 2001. Intercept, slope, and r^2 values are from regressions of percent cover in the 0.4-km landscapes ($P_{0.4,i,j}$) versus the 10-km landscapes ($P_{10,i,j}$) (n = 3,230 routes). Standard errors for the intercept and slope are given in parentheses. Mean positive and negative differences ($P_{0.4,i,j} - P_{10,i,j}$) are also shown.

Cover type	Intercept	Slope	r^2	Mean + difference	Mean – difference
Developed Open Space	3.23 (0.086)	0.97 (0.019)	0.45	3.82	–1.09
Developed Low Intensity	1.06 (0.060)	0.88 (0.019)	0.40	1.89	–0.85
Developed Medium Intensity	0.17 (0.029)	0.85 (0.017)	0.44	0.72	–0.40
Developed High Intensity	0.08 (0.014)	0.52 (0.021)	0.16	0.37	–0.17
Deciduous Forest	0.27 (0.158)	0.85 (0.006)	0.87	3.87	–5.19
Evergreen Forest	0.08 (0.170)	0.90 (0.007)	0.84	4.45	–4.19
Mixed Forest	–0.02 (0.037)	0.96 (0.005)	0.92	1.36	–0.96
Shrub–Scrub	0.45 (0.187)	0.94 (0.006)	0.88	4.55	–3.91
Barren Land	0.01 (0.028)	0.73 (0.009)	0.68	0.65	–0.58
Grassland–Herbaceous	0.95 (0.145)	0.93 (0.007)	0.86	3.62	–3.07
Pasture–Hay	1.09 (0.126)	1.13 (0.009)	0.82	5.13	–2.06
Cultivated Cropland	1.47 (0.184)	0.98 (0.007)	0.86	5.74	–3.27
Open Water	0.47 (0.046)	0.22 (0.006)	0.31	1.15	–2.84
Woody Wetland	0.19 (0.072)	0.82 (0.008)	0.78	1.82	–1.97
Herbaceous Wetland	0.13 (0.042)	0.80 (0.009)	0.71	1.07	–0.75

indicate that most BBS landscapes do not contain either a large excess or deficit of a particular cover type (i.e., habitat) compared with larger landscapes. Therefore, bird assemblages along BBS routes (within 0.4-km landscapes) are probably not fundamentally different from those in the greater surrounding landscape, given that the full suite of habitats is available near the routes. For some routes and some species, there may be bias in counts of individuals; however, this error is more likely due to other factors (e.g., attraction to or avoidance of roads and highways) rather than habitat availability.

There were a few cover types that tended to be misrepresented in the 0.4-km landscapes. Notably, open water was underrepresented (proportional error, m = 0.22; Table 2); 0.4-km landscapes had, on average, less than half as much open water as the 10-km landscapes (1.2% vs. 3.1%). This result may be explained by a lack of roads and highways (and, thus, a lack of BBS routes) parallel to large water bodies or parallel for only a short distance of the shoreline. Developed open space was overrepresented (constant error, b = 3.23; Table 2); 0.4-km landscapes had, on average, twice as much of this cover type (3.8% vs. 1.1%). This overrepresentation is probably due to developed open space being serviced by the type of secondary highways and roads that are often used as BBS survey routes. Anthropogenic cover types (e.g., developed open space, developed low-intensity, pasture–hay, and cropland) tended to be more common in the 0.4-km landscapes than in the 10-km landscapes. Also, as expected, natural land-cover types (e.g., forest) were more common in the larger landscapes than in the smaller. These findings are not surprising, given that human modifications to a landscape should be most pronounced adjacent to roads and result in a loss of natural cover.

We did not find any clear indication that local representativeness was influenced by the frequency of the cover type. Some infrequent cover types (e.g., developed land of medium and high intensity, barren land, and mixed forest) were as representative as common cover types (e.g., deciduous and evergreen forests, shrub, grassland, pasture, and cropland) (Tables 1 and 2). Common cover types (>10% cover) tended to have a greater percentage-point difference between the 0.4-km and 10-km landscapes, whereas infrequent cover types (<3% cover) tended to have a greater percent difference. For a common cover type, a difference in percent cover of 15% versus 20% might be just as representative as a difference of 1% versus 2% for an infrequent cover type.

Our assessment of local representativeness was based on metrics (Table 2) that are parameters of a set of routes, not individual routes. For any one route, the 0.4-km landscape could be very different from the 10-km landscape. Furthermore, a small set of routes (e.g., $n < 20$) also may not adequately represent the land cover in the 10-km landscapes. Therefore, researchers should be cautious in conducting analyses of BBS and NLCD 2001 data from only a few routes. Many procedures for estimating population trend (route-regression, hierarchical log-linear models) typically combine multiple BBS routes (10s to 100s) to arrive at estimates and make inferences for a larger region (Geissler and Sauer 1990, Link and Sauer 2002, Sauer and Link 2011). Most published studies of BBS data avoid making inferences (about population trends, abundances, and habitat use) based on data from a single or small set of routes. Nonetheless, the approach that we used to assess representativeness could be applied to any set of routes and landscape sizes; the researcher could then decide whether their select group of routes is representative enough.

Regional representativeness.—Although BBS routes are not completely randomly placed within BCRs, as a collective group most sets of routes represent very well the landscape composition within their BCR (Table 3). From a sampling perspective, most BCRs appear to be sufficiently "sampled" by their constituent BBS routes. However, in many BCRs, there were usually one or two cover types that were either over- or underrepresented in the 0.4-km landscapes, as indicated by a difference of >5 percentage points in the percent cover between the combined 0.4-km landscapes and the entire BCR. None of the BCRs had widespread differences (extreme values of $P_{\text{comb},i} - P_{\text{BCR},i}$) for all cover types; hence, the values for mean absolute difference were all relatively low.

Table 3. Regional representativeness of the 0.4-km Breeding Bird Survey route-landscapes for each Bird Conservation Region (BCR). Representativeness is assessed by comparing the percent cover of each of the 15 NLCD (National Land Cover Database 2001) cover types in the combined 0.4-km landscapes with the percent cover in the entire BCR (PP = percentage points).

BCR	Routes analyzed	Percent of BCR area [a]	Mean absolute difference [b]	Maximum positive difference [c]	Maximum negative difference [c]	Cover types ≥5 PP difference [d]	Cover types ≥2.5 PP difference [d]
5	119	1.70	2.11	4.60 (21)	–13.74 (42)	1	3
9	228	0.96	1.74	4.89 (82)	–10.26 (52)	1	4
10	176	0.97	1.10	2.37 (81)	–4.62 (42)	0	2
11	99	0.65	1.13	3.58 (21)	–7.06 (71)	1	3
12	114	1.46	1.82	4.47 (21)	–5.50 (90)	1	4
13	78	2.50	1.20	5.57 (81)	–3.28 (42)	1	4
14	125	2.16	1.84	5.38 (21)	–7.88 (41)	2	3
15	36	2.09	1.06	4.61 (21)	–5.81 (31)	1	3
16	180	1.08	1.10	2.97 (21)	–4.56 (42)	0	2
17	100	0.75	0.96	2.56 (21)	–3.85 (71)	0	2
18	111	0.86	0.81	3.38 (21)	–3.10 (52)	0	3
19	95	0.68	0.76	3.50 (21)	–2.62 (71)	0	2
20	16	0.86	1.73	8.35 (71)	–6.67 (42)	2	4
21	57	0.88	1.02	3.14 (81)	–2.17 (41)	0	2
22	192	1.07	1.12	5.05 (82)	–2.67 (41)	1	3
23	122	1.55	1.03	2.39 (21)	–2.64 (41)	0	1
24	118	1.13	1.37	4.44 (81)	–8.15 (41)	1	3
25	68	0.96	1.43	3.06 (21)	–4.69 (90)	0	3
26	40	1.04	2.11	4.75 (21)	–11.47 (82)	1	4
27	231	1.43	1.21	3.78 (21)	–4.38 (90)	0	2
28	325	2.19	1.32	3.94 (81)	–7.96 (41)	1	3
29	112	1.75	1.69	5.58 (81)	-4.45 (42)	1	5
30	111	4.12	1.43	5.25 (82)	–3.38 (11)	1	2
31	57	1.91	0.74	3.22 (21)	–1.39 (11)	0	1
32	99	1.77	1.25	4.99 (21)	–2.90 (71)	0	4
33	70	0.89	1.57	4.41 (82)	–8.75 (52)	1	3
34	32	0.79	0.77	2.80 (21)	–4.50 (52)	0	2
35	44	0.72	1.14	4.99 (21)	–6.29 (52)	1	2
36	21	0.95	2.37	4.70 (82)	–15.55 (52)	1	4
37	24	1.17	2.99	11.66 (82)	–6.79 (95)	4	5

[a] Percent of total BCR area represented by the combined area of all 0.4-km BBS route-landscapes.
[b] Mean absolute difference is the difference, $|P_{comb',i} - P_{BCR',i}|$, averaged over all NLCD cover types.
[c] Maximum positive and negative differences are for the cover type *i* (shown in parentheses) that had the greatest difference, $P_{comb',i} - P_{BCR',i}$.
[d] The number of cover types in which $P_{comb',i} - P_{BCR',i}$ exceeded either 5 or 2.5.

These results are informative and useful in two ways. First, as with good local representation, a high level of regional representation suggests that the BBS data are a thorough and relatively accurate portrayal of region-wide bird dynamics, notwithstanding the effects of other factors previously mentioned. For example, in BCR 19 (in the Great Plains) and BCR 31 (in south Florida), all but two of the cover types are well represented [$-2 < (P_{comb,i} - P_{BCR,i}) < +2$] on the BBS routes. Therefore, the BBS routes in these two greatly different BCRs likely sample their constituent bird faunas fairly well. Second, the results indicate the types of land cover that new BBS routes should try to sample within each BCR. For example, evergreen forest is undersampled in BCR 5 ($P_{comb,i} - P_{BCR,i} = -13.7$), even though it generally composes a large proportion of the BBS route-landscapes and the BCR area. It may be that an insufficient number of BBS routes penetrate the extensive coniferous forests in this BCR located in the Pacific Northwest (Fig. 1). The same reasoning may explain the underrepresentation ($P_{comb,i} - P_{BCR,i} = -15.5$) of shrub land in BCR 36 of south Texas. On the other hand, some land-cover types are overrepresented on BBS routes, such as cropland ($P_{comb,i} - P_{BCR,i} = 11.7$) in BCR 37 on the western Gulf Coast. This suggests that new routes in this BCR should not be established in areas of expansive cropland.

Other issues in the use of land cover with BBS data.—Although our study revealed that BBS landscapes are sufficiently representative (local and regional) for most of the NLCD 2001 cover types examined, there are related issues in the use of BBS and NLCD 2001 data that we did not address. First, we did not examine temporal changes in BBS landscapes. Temporal change in land-cover composition within BBS landscapes (i.e., along roadsides) may occur at a different rate than change in roadless areas or in larger regional landscapes (Bart et al. 1995, Keller and Scallan 1999). We also did not compare spatial configuration (e.g., mean size of a habitat patch) within BBS landscapes to larger landscapes. Second, on a continental level, present BBS routes may not be located in a way that fully captures all the environmental variation in a given region (Lawler and O'Connor 2004). Third, our study did not test for a road effect on bird surveying. If certain bird species either select or avoid roads (due to traffic, noise,

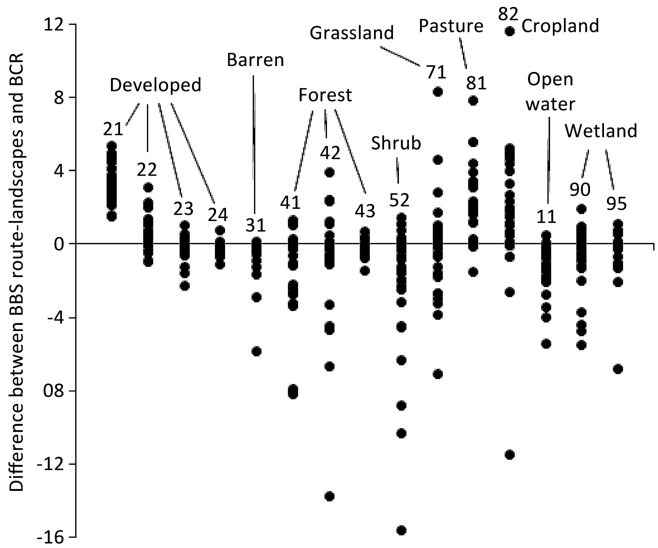

Fig. 3. Difference between the percent cover within the combined 0.4-km landscapes and the BCR (Bird Conservation Region), $P_{\mathrm{comb},i} - P_{\mathrm{BCR},i}$, for each land cover type (*i*) of the National Land Cover Database 2001(NLCD) and each BCR. Number labels represent NLCD code numbers (see Table 1).

and other anthropogenic factors), those species will not be accurately sampled by the BBS protocol, even if BBS landscapes are similar to larger landscapes (Hanowski and Niemi 1995, Sutter et al. 2000, Dieni and Scherr 2004, Howell et al. 2004). Lastly, species detection probability (i.e., imperfect detection of some species) is also a crucial factor in assessing the "quality" of BBS data, apart from any effect that landscape composition may have on data quality.

Thogmartin et al. (2004a) and Gallant (2009) stressed that researchers should know the limitations of the land-cover databases that they use in their studies. In addition to accuracy, important issues to consider include the source and type of imagery, resolution, temporal period of imaging, temporal changes in land cover, computer algorithms used to classify pixels, and the producer's recommendation on proper use. Within the NLCD 2001 data (and other remotely sensed data), some amount of error exists in misclassifying 30 × 30 m pixels to the "wrong" cover type (Wickham et al. 2010). Users' and producers' accuracies for the NLCD 2001 cover types range from about 50% to 90% (Wickham et al. 2010). Ironically, open water has the greatest classification accuracy, yet is one of the least representative cover types. Although misclassification error has likely not affected our analyses (i.e., there is no reason to suspect that the percent error rate should be higher or lower in the larger landscapes than in the smaller landscapes), such error is a general concern of producers and users of extensive land-cover databases. Accuracy can be improved substantially by aggregating similar cover types (e.g., deciduous, evergreen, and mixed forest) into a single cover type (Wickham et al. 2010).

A practical consideration in using NLCD 2001 data in conjunction with BBS data is whether the cover types represent habitat. We used these data to assess representativeness of BBS routes simply because the NLCD 2001 database is one of the most recent and extensive sources of land-cover data for the United States (Homer et al. 2007). Obviously, many NLCD 2001 cover types represent non-habitat to many bird species, and for some studies these cover types could essentially be lumped into a non-habitat category. Other cover types (e.g., the three forest categories) may not be divided finely enough to capture specific breeding and foraging habitat requirements of some species, particularly if these requirements are based on vegetative composition instead of structure. For other species, the relatively broad NLCD 2001 cover types likely represent structural habitat distinctions important to the species.

We believe that researchers using BBS data could make greater use of NLCD 2001 data, particularly in regional-scale analyses involving the search for general bird–habitat relationships among tens to hundreds of BBS routes. However, the onus is on the individual researcher to decide (on the basis of our results or their own assessment) whether BBS routes are sufficiently representative and NLCD data sufficiently descriptive for their particular planned study. Land-cover classification error may be a legitimate concern in some applications of NLCD data. It can be mitigated to some extent by combining cover types, but this also results in loss of resolution of different habitat types. Despite these issues, advances in regional-level bird conservation could emerge from research and assessment that fully utilize BBS data as well as NLCD data.

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