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Note

American Woodcock Singing-Ground Survey Sampling of Forest Type and Age

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ABSTRACT The American Woodcock Conservation Plan calls for halting and reversing declines of American woodcock (*Scolopax minor*) populations through creation and management of early successional forest (ESF). Counts of displaying male woodcock along routes of the American woodcock singing-ground survey (SGS) are used to assess regional population status and trends, and there is a need to assess whether SGS routes represent the region. We assessed whether individual SGS routes (330-m buffers) in the Boreal-Hardwood and Prairie-Hardwood Transitions of Minnesota, USA represented land covers within local landscapes, defined using simulated 10-minute blocks, and whether the routes, in aggregate, represented land covers of our study region. Our land covers included non-forest classes, age-based ESF (≤20 years), and persisting classes for deciduous-mixed and evergreen forests and woody wetlands. We found that the median value of mean absolute differences (MAD) between percentages for route buffer and block cover classes was 3.78 percentage points. Twenty-two of 81 (27%) route buffers had MAD values ≥5 percentage points. Within Minnesota, more of these routes (19 of 22) occurred in the Boreal-Hardwood Transition than in the Prairie-Hardwood Transition. Relative to local landscapes, route buffers most frequently and strongly under-represented open water, barren land, evergreen ESF, persisting woody wetlands, and woody wetland ESF and over-represented developed land and grassland-pasture. When we compared routes in aggregate to our study region, the magnitude of percentage point differences for individual covers did not exceed 5, except for open water. Given the relatively small differences we observed, we conclude that SGS routes well represent land covers within our study region.

KEY WORDS aggregation, American woodcock, compositional analysis, early successional forest, forest disturbance, roadside survey, *Scolopax minor*, singing-ground survey, young forest.

The American woodcock (*Scolopax minor*; i.e., woodcock) is a popular gamebird that has experienced long-term (1968–2016) population declines in many states of the northeastern and midwestern United States and neighboring provinces of Canada (Seamans and Rau 2016). Researchers and managers have attributed woodcock declines largely to the loss and degradation of early successional forests (ESF) due to land-use conversion, changing forest management practices, cessation of farm abandonments, and disrupted natural disturbance regimes (Trani et al. 2001, Kelley et al. 2008). Through creation and management of ESF (small diameter forests ≤20 years of age), the American Woodcock Conservation Plan (AWCP; Kelley et al. 2008) calls for restoration of woodcock populations to densities observed during the 1970s (0.03 singing males per manageable forest hectare range wide). The AWCP set a short-term goal of stopping declines of ESF and woodcock populations by 2012 and a longer-term goal of ESF acreage and woodcock population growth by 2022. Regional initiatives, including the Upper Great Lakes Young Forest Initiative (YFI) were established to implement AWCP habitat goals (Cooper 2008). The YFI region encompasses all or portions of Minnesota, Wisconsin, and Michigan, USA, within Bird Conservation Regions (BCRs) 12 (Boreal-Hardwood Transition) and 23 (Prairie-Hardwood Transition). Ultimately, the restoration of YFI population densities through ESF creation and management is expected to "...provide adequate opportunity for utilization of the woodcock resource" (Kelley et al. 2008:2).

Quantifying progress toward AWCP population density goals is tied to annual indices of singing males provided by the singing-ground survey (SGS; Kelley et al. 2008). Since 1968, observers for the SGS conducted counts of courting woodcock males along secondary roads, or routes, located approximately in the center of 10-minute-degree blocks (i.e.,

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blocks) randomly selected within states and provinces (Seamans and Rau 2016). From 1968 to 2016, the YFI states of Michigan and Wisconsin had a statistically significant decline and an insignificant decline, respectively, with Minnesota being the only state or Canadian province to show a significant increase in woodcock counts (Seamans and Rau 2016). During the most recent decade (2006–2016), Seamans and Rau (2016) documented a significant increase in woodcock counts along SGS routes for Minnesota, whereas there were statistically insignificant increases in Michigan and Wisconsin. Although the long-term trend is discouraging, these findings suggest that the short-term goal of halting woodcock population declines has been met in the YFI region.

A critical assumption underlying such inferences is that woodcock counts along SGS routes provide an unbiased index of statewide woodcock population status and trends, and this assumption is questioned because roadside SGS trends may not be representative of the regional woodcock population (D.J. Case and Associates 2010). Currently, there are no independent estimates of statewide woodcock population size and trends with which to validate this assumption. Previous studies compared land cover near SGS and breeding bird survey routes to land cover at larger extents to indirectly evaluate the ability of road-side counts to represent regional bird population status and trends (Jentoft 2000; Morrison et al. 2006; Veech et al. 2012, 2017; Nelson and Andersen 2013).

We evaluated whether SGS routes represented land cover classes, including components of woodcock habitat. Our assessment of SGS route representativeness is timely because the advent of a geospatial data set that includes forest age enables inclusion of ESF (≤20 years of age) and recent data suggests that the goals of halting the declines of ESF area and woodcock populations have been met (Cooper 2008, Miles 2015, Seamans and Rau 2016). Our objective was to test the hypothesis that land covers, including forest age classes, associated with SGS routes accord with land covers at local and regional scales, ultimately informing discussions about whether route counts reflect population status at larger scales.

STUDY AREA

We conducted this study within the western portion of the Upper Great Lakes YFI region, specifically, within the Minnesota portion of BCRs 12 and 23. Shared bird communities, habitats, and natural resource management issues are used to delineate BCRs (Matteson et al. 2009). In Minnesota, BCRs 12 and 23 are closely aligned with the Laurentian Mixed Forest Province (212), and Eastern Broadleaf Forest Province (222), respectively (https://www.dnr.state.mn.us/ecs/index.html, accessed 28 Apr 2018).

Within BCR 12, important natural features include lakes, bogs, and other water bodies, northern hardwood and coniferous forests, and nutrient-poor soils (U.S. North American Bird Conservation Initiative Committee [USNABCIC] 2000). Annual precipitation ranges from approximately 81 cm in the east, to 53 cm in the west. Average annual temperatures range from approximately 1°C in the north to 4°C in the south. Together, these factors result in warmer and drier conditions in the southwest, and cooler and moister conditions in the northeast. Landscape features include thin glacial deposits over bedrock with rugged lake-dotted terrain; hummocky or undulating plains with deep glacial drift; and large, flat, poorly drained peatlands (https://www.dnr.state.mn.us/ecs/222/index.html, accessed 3 Apr 2018). Average elevation is 404 m ranging from 183 m to 701 m. Land conversion to agricultural areas and some urbanization, exploitation of timber and natural resources, and reduced tree species richness have occurred in BCR 12 (Matteson et al. 2009).

Before extensive agricultural land-use conversion and the development of several major urban centers, BCR 23 historically captured a gradient from prairie in the south and west to beech (*Fagus grandifolia*)-maple (*Acer* spp.) forests in the north and east with oak (*Quercus* spp.) savannas occurring between these 2 vegetation communities (USNABCIC 2000, Knutson et al. 2001). The northwestern and central portions of the province are characterized by thick (30–90 m) deposits of glacial drift that are highly calcareous. Post-glacial events deposited silt across the southeastern part of the province. Erosion of streams draining into the Mississippi Valley dissected the uplands. Average elevation is 348 m ranging from 189 m to 514 m. Average annual precipitation decreases from approximately 90 cm in the southeast to 60 cm in the northwest. Normal annual temperatures decrease from 8°C in the southeast to 3°C in the northwest (https://www.dnr.state.mn.us/ecs/212/index.html, accessed 3 Apr 2018).

Based on SGS count trend analysis, Seamans and Rau (2016) reported a significant increase in woodcock counts for Minnesota (2.43%) and insignificant increases for Michigan and Wisconsin between 2006 and 2016. Minnesota also has a relatively high proportion of SGS routes with verified locations (80%) compared to Wisconsin (39%) and Michigan (56%). Therefore, this study is constrained to the Minnesota portion of the YFI (Fig. 1); hereafter, references to Minnesota refer to those portions of BCRs 12 and 23 encompassing 13,785,138 ha within the state boundary, excluding open water of Lake Superior. The state of Minnesota has identified 30 bird species associated with forests, open woodlands, or scrubs as species of greatest conservation need, including woodcock, northern goshawk (*Accipiter gentilis*), olive-sided flycatcher (*Contopus cooperi*), red-headed woodpecker (*Melanerpes erythrocephalus*), golden-winged warbler (*Vermivora chrysoptera*), and Bell's vireo (*Vireo bellii*; Minnesota Department of Natural Resources 2016).

METHODS

Singing-Ground Survey Routes

We created a geospatial data layer representing verified SGS routes by using global positioning system (GPS) coordinates for 10 stops/route submitted by individual observers responsible for SGS counts (Fig. 1). United States Fish

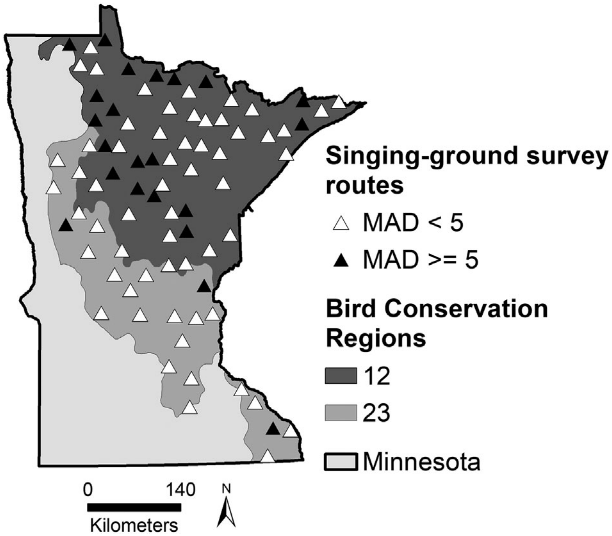

Figure 1. Locations of verified American woodcock singing-ground survey routes within the Minnesota, USA portion of Bird Conservation Regions 12 (Boreal-Hardwood Transition) and 23 (Prairie-Hardwood Transition). Routes are visualized based on mean absolute difference (MAD) in percent covers between route buffers and 10-minute-degree blocks. Means are based on absolute differences for 13 cover classes: open water; developed; barren land; shrub-scrub; cultivated crops; emergent herbaceous wetlands; grassland-pasture; persisting (>20 years) deciduous-mixed, evergreen, and woody wetland forests; and early successional (≤20 years) deciduous-mixed, evergreen, and woody wetland forests. Route buffers had radii of 330 m, and blocks were simulated to be centered on route midpoints. Land cover data nominally represented 2011 and forest age data nominally represented 2009.

and Wildlife Service (USFWS) personnel verified that GPS coordinates fell along mapped paths for SGS routes. We produced a vector layer representing verified routes by connecting all stop locations within each route in sequential order (stops 1–2, stops 2–3, ... stops 9–10) using straight lines. Where roads curved or turned, we edited route lines to match actual roads by manually aligning routes using a heads-up digitizing approach, displaying high-resolution digital imagery and transportation vector layers as background reference of roads. We edited routes where the perpendicular distance between a route vertex and the actual road segment exceeded 30 m, a distance that matched the spatial resolution of the ESF geospatial data set used for habitat analyses, described below. A distance <30 m would not have substantially altered the identity of pixels near the route or the composition of woodcock habitat sampled by the route.

Personnel with USFWS have verified observer-submitted GPS coordinates for 81 of 101 (80%) routes within Minnesota. Based on visual interpretation, the spatial distribution of verified routes in Minnesota appeared to be random, suggesting that verified routes in Minnesota provide an unbiased sample of all routes (Fig. 1).

ESF Geospatial Layer

We mapped ESF using a 30-m spatial resolution raster data set that assigned age classes to deciduous, evergreen, mixed, and woody wetland forest classes in the National Land Cover Database of 2011 (Homer et al. 2015), published as a United States Department of Agriculture Forest Service Research Dataset (Garner et al. 2015, 2016). We defined forest age as time since a canopy-clearing disturbance with subsequent regrowth between 1990 and 2009 as detected by a vegetation-change-tracker algorithm (Huang et al. 2010) with a winter-imagery-enhancement (Stueve et al. 2011). The nominal vintage of the Research Dataset was 2009. For a complete understanding of the Research Dataset, we encourage readers to reference an accuracy assessment reported by Garner et al. (2015) and Tavernia et al. (2016). To define ESF, we used a single age class, 1–20 years old, a definition consistent with the AWCP, which used a 20-year time horizon to define suitable habitat for woodcock (Kelley et al. 2008). Forest >20 years old was categorized as persisting forest. The Research Dataset contained an "other" forest class where the National Land Cover Database of 2011 showed either shrub-scrub or grassland-herbaceous classes and the corresponding location was identified as forest by the vegetation-change-tracker algorithm with a winter-imagery-enhancement. This avoided potential omissions of ESF where the National Land Cover Database of 2011 mapped grassland-herbaceous cover following a tree canopy disturbance or shrub-scrub cover during tree canopy regeneration following a disturbance, neither of which resulted in permanent land-use change.

We considered deciduous-mixed ESF, shrub-scrub, and woody wetland ESF as cover classes with the potential for nesting, brood rearing, or foraging and grassland-pasture as a cover class with the potential to serve as singing grounds or roosting areas (McAuley et al. 2013). Successional stage or forest structure, rather than plant species composition, is an indicator of diurnal habitat quality for woodcock, although conifer stands may be little used in northern parts of the breeding range (Straw et al. 1994, Kelley et al. 2008, McAuley et al. 2013). Accordingly, we aggregated deciduous and mixed forest cover classes into a single deciduous-mixed cover class and retained evergreen forest as a separate class as an assumed non-habitat component. We reclassified "other" forest pixels as either deciduous-mixed or evergreen forests thematic classes using a geographic nearest neighbor approach. With respect to non-forest cover classes, we aggregated National Land Cover Database of 2011 grassland-herbaceous and pasture-hay into a grassland-pasture cover class and combined developed open space, developed low intensity, developed medium intensity, and developed high intensity into one developed class. Hereafter, we refer to the modified Research Dataset as our ESF geospatial layer. Unless otherwise indicated, we conducted all geoprocessing in the geographic information system software ArcMap 10.2.2 (Environmental Systems Research Institute [ESRI], Redlands, CA, USA).

Local and Regional Representativeness

For our assessment of SGS routes, we adapted methods used by Veech et al. (2012, 2017) to assess the representativeness of routes in the Breeding Bird Survey (BBS), a continental-scale, roadside survey used to monitor the status and trends of breeding bird species in North America (https://www.pwrc.usgs.gov/bbs/, accessed 23 Mar 2018). We evaluated the ability of SGS routes to represent local landscapes (i.e., local representativeness) by comparing percent covers of 330-m-radius route buffers to simulated blocks centered on route midpoints. The mean area of a route buffer was 418.83 ha (range = 385.49–457.96 ha) and of a block was 24,220.29 ha (range = 23,048.52–24,234.93 ha). We chose 330 m to approximate the distance over which observers can detect woodcock (Tautin et al. 1983), and we defined the local landscape using simulated blocks because routes were established within randomly selected 10-minute-degree blocks (Seamans and Rau 2016). Both choices are consistent with a previous assessment of SGS representativeness (Nelson and Andersen 2013).

We determined percent of cover class i ($i = 1–13$) for each route buffer j ($j = 1–81$) and associated block based on pixel counts. If a cover class was absent from a block and, *ipso facto*, from the associated route buffer, we excluded it from all subsequent calculations of local representativeness. For each cover class, we linearly regressed percent covers in route buffers ($P_{r,i,j}$) against percent covers in corresponding blocks ($P_{b,i,j}$):

$$P_{r,i,j} = b + mP_{b,i,j}, \quad (1)$$

where b is a y-intercept representing a constant difference between buffers and blocks, and m is a slope parameter representing a difference proportional to block percent cover. The y-intercept and slope parameters capture systematic differences, but there also are random or unsystematic differences between route buffers and blocks. Consequently, we report coefficient of determination (r^2) as a measure of the proportion of total variation in $P_{r,i,j}$ explained by $P_{b,i,j}$. Route buffers perfectly represent local landscapes where $b = 0$, $m = 1$, and $r^2 = 1$.

For each route, we calculated a mean absolute difference (MAD_j) as:

$$\mathrm{MAD}_j = \Sigma_{i=1}^{i_p} \left| P_{r,i,j} - P_{b,i,j} \right| / i_p, \quad (2)$$

where i_p represents the number of cover classes present within block j and potentially present in route buffer j. A MAD_j close to 0 indicates agreement between a route buffer and block across all cover classes. For each cover class, we report a mean absolute difference (cMAD_i) as:

$$\mathrm{cMAD}_i = \Sigma_{i=1}^{j_p} \left| P_{r,i,j} - P_{b,i,j} \right| / j_p, \quad (3)$$

where j_p represents the number of blocks where a cover class was present and route buffers where a cover class could have been present.

We assessed the regional representativeness of routes for cover class i using difference ($D_{a,i}$) calculated as:

$$D_{a,i} = P_{a,i} - P_{MN,i}, \quad (4)$$

where $P_{a,i}$ is the percent cover of cover class i for route buffers in aggregate and $P_{MN,i}$ is the percent cover of cover class i for the Minnesota study area (subset defined by state intersection with BCRs 12 and 23). Note that $D_{a,i}$ addresses percentage point differences not percentage differences. This measure may fail to identify rare cover classes where absolute differences are small but relative differences between route buffers and Minnesota are large. Therefore, we also calculated a relative difference for each cover class ($D_{r,i}$):

$$D_{r,i} = \left(P_{a,i} - P_{MN,i}\right) / P_{MN,i} \times 100. \quad (5)$$

We carried out the above calculations in the R programming environment (R Core Team 2017).

RESULTS

Dominant land covers (>10%) for route buffers, blocks, and Minnesota included persisting deciduous-mixed forest and persisting woody wetlands, whereas barren land, shrub-scrub, deciduous-mixed ESF, persisting evergreen forest, evergreen ESF, and woody wetland ESF were rare (<5%; Table 1). Rankings of cover classes were broadly similar for buffers, blocks, and Minnesota, with some exceptions. For example, open water was <1% of route buffers but was more common for blocks or for Minnesota and cultivated cropland cover was greater in Minnesota than in either route buffers or blocks. Generally, cover classes with greater median percent covers also possessed greater ranges of percent cover values across route buffers and blocks (Table 1).

Table 1. Percent covers for buffers of singing-ground survey routes for American woodcock, 10-minute-degree blocks, and Minnesota, USA. Median values are reported for buffers and blocks; minimum and maximum values are reported parenthetically. Sample size (n) is reported for route buffers and blocks. Route buffers had a radius of 330 m, and 10-minute-degree blocks were simulated to be centered on route midpoints. Minnesota refers to the region defined by the intersection of the state with Bird Conservation Regions 12 (Boreal-Hardwood Transition) and 23 (Prairie-Hardwood Transition). Land cover data nominally represented 2011 and forest age data nominally represented 2009.

Cover class	330-m-radius buffer	10-minute block	n	Minnesota
Open water	0.17 (0.00–48.95)	4.02 (<0.01–73.22)	81	8.60
Developed	8.03 (4.94–15.83)	2.94 (0.28–19.65)	81	5.44
Barren land	0.00 (0.00–1.79)	0.03 (<0.01–16.25)	61	0.21
Shrub-scrub	0.46 (0.00–5.64)	0.30 (<0.01–6.67)	80	0.54
Cultivated crops	2.80 (0.00–90.92)	2.64 (0.01–88.00)	76	14.28
Emergent herbaceous wetlands	4.34 (0.00–30.97)	5.18 (0.02–48.93)	81	8.01
Persisting deciduous-mixed forest	22.31 (0.35–67.09)	26.35 (0.05–68.16)	81	25.10
Early successional deciduous-mixed forest	0.91 (0.00–18.69)	1.40 (0.01–18.15)	81	2.63
Persisting evergreen forest	1.98 (0.00–54.35)	2.34 (0.02–33.38)	81	4.58
Early successional evergreen forest	0.00 (0.00–19.15)	0.14 (<0.01–14.08)	71	0.36
Grassland-pasture	10.60 (0.00–60.63)	5.38 (<0.01–44.09)	80	11.14
Persisting woody wetland	11.30 (0.00–86.07)	16.34 (0.02–84.06)	81	18.15
Early successional woody wetland	0.37 (0.00–8.04)	0.77 (<0.01–6.17)	73	0.97

Across all route buffers, the median MAD value was 3.78, and 22 of 81 (27%) route buffers had MAD values >5 percentage points. Nineteen of 22 route buffers with MAD values >5 percentage points occurred in BCR 12 (Fig. 1). With respect to individual cover classes, only open water, cultivated croplands, persisting deciduous-mixed forest, grassland-pasture, and persisting woody wetlands possessed cMAD values ≥5 percentage points (Table 2).

Examination of our regression results revealed differences between route buffers and blocks due to systematic and unsystematic differences (Fig. 2; Table 2). Developed land provided an example of systematic (intercept = 6.9; slope = 0.38) and unsystematic ($r^2 = 0.21$) differences. The intercept (2.77) of grassland-pasture reflected systematic differences, but its slope (1.14) was near 1. An r^2 value of 0.73 suggested that unsystematic differences were relatively unimportant for grassland-pasture. Woody wetland ESF was an example of a class with unsystematic ($r^2 = 0.46$) but not systematic (intercept = 0.13; slope = 0.87) differences. Neither systematic nor unsystematic differences were strong for deciduous-mixed ESF, which showed intercept (0.11) and slope (0.83) values close to 0 and 1, respectively, and a reasonably high r^2-value (0.62).

Negative differences (i.e., under-representation) between route buffers and blocks were relatively common for open water, barren land, evergreen ESF, persisting woody wetlands, and woody wetland ESF (Fig. 3). Negative differences ≤−5 were frequent for open water, persisting deciduous-mixed forest, and persisting woody wetland. Positive differences (i.e., over-representation) were common for developed land, and positive differences ≥5 were frequent for developed land and grassland-pasture.

Across route buffers in aggregate, most cover classes were within 5 percentage points of their statewide values (Table 2). Extreme difference values corresponding to over- and under-representation were 4.50 for grassland-pasture and −6.57 for open water, respectively. Based on relative differences, open water and barren land were more than halved (≤−50%) in route buffers compared to the state (Table 2). No cover classes were doubled (≥100%) in route buffers.

DISCUSSION

We found that over a quarter of SGS route buffers had MAD values ≥5 when compared to blocks, and based on published precedent (Veech et al. 2012, 2017), we identified these route buffers as failing to provide good representation of their local surroundings. Individual cover classes with large absolute differences included grassland-pasture, a cover class associated with courtship and roosting opportunities for woodcock (McAuley et al. 2013). Nonetheless, when we considered route buffers in aggregate, differences between land covers for route buffers and Minnesota were generally ≤5 percentage points. Given that we defined our land cover types to capture woodcock habitat needs and assuming that woodcock populations are habitat limited (Kelley et al. 2008), these latter results support the use of SGS counts as an index to infer woodcock population trends for Minnesota.

Across cover classes, we observed the greatest cMAD values between route buffers and blocks for open water, cultivated cropland, grassland-pasture, persisting deciduous-mixed forest, and persisting woody wetland. For some cover classes, such as developed land and open water, differences had a systematic component, being either consistently positive or negative, resulting in over- or under-representation of a class within route buffers. Such systematic differences could be due to aspects of the SGS sampling design, such as avoiding route placement in areas dominated by water features (R. D. Rau, USFWS, unpublished document); land cover dynamics dependent on road proximity, such as new housing development; biases in the ESF geospatial layer; or some combination of these factors. Some land cover classes, for example, woody wetland ESF, displayed unsystematic, or ostensibly random, differences between route buffers and blocks; these unsystematic differences can influence the degree of concordance between buffers and blocks but would not result in a class being consistently over- or under-represented by route buffers.

Table 2. Metrics evaluating the ability of American woodcock singing-ground survey route buffers to represent cover class percentages in 10-minute-degree blocks and Minnesota, USA. Intercept, slope, and r^2 correspond to regressions of route buffer percent covers against percent covers for 10-minute-degree blocks. Standard errors for intercepts and slopes are reported parenthetically. We also present the mean absolute difference between percent covers in route buffers and 10-minute-degree blocks (cMAD) and the absolute (D_a) and relative (D_r) differences between percent covers in the aggregated route buffers and Minnesota. Route buffers had a radius of 330 m, and 10-minute-degree blocks were simulated to be centered on route midpoints. Minnesota refers to the region defined by the intersection of the state with Bird Conservation Regions 12 (Boreal-Hardwood Transition) and 23 (Prairie-Hardwood Transition). Land cover data nominally represented 2011 and forest age data nominally represented 2009.

Cover class	Intercept	Slope	r^2	cMAD	D_a	D_r
Open water	1.72 (0.81)	0.04 (0.06)	0.01	6.70	−6.57	−76.40
Developed	6.9 (0.39)	0.38 (0.08)	0.21	4.81	2.86	52.57
Barren land	0.1 (0.04)	−0.01 (0.02)	0.00	0.51	−0.14	−66.67
Shrub-scrub	0.36 (0.13)	1.07 (0.13)	0.48	0.62	0.42	77.78
Cultivated crops	1.69 (1.28)	0.99 (0.05)	0.82	5.13	−0.11	−0.77
Emergent herbaceous wetlands	2.06 (0.89)	0.57 (0.08)	0.41	4.42	−1.25	−15.61
Persisting deciduous-mixed forest	2.30 (2.15)	0.83 (0.07)	0.64	8.21	−0.97	−3.86
Early successional deciduous-mixed forest	0.11 (0.35)	0.83 (0.07)	0.62	1.53	−0.04	−1.52
Persisting evergreen forest	0.55 (1.01)	1.36 (0.11)	0.67	4.05	3.57	77.95
Early successional evergreen forest	−0.07 (0.19)	1.53 (0.10)	0.76	0.52	0.30	83.33
Grassland-pasture	2.77 (1.33)	1.14 (0.08)	0.73	6.62	4.50	40.39
Persisting woody wetland	1.29 (1.62)	0.74 (0.06)	0.66	7.61	−2.64	−14.55
Early successional woody wetland	0.13 (0.20)	0.87 (0.11)	0.46	0.79	0.06	6.19

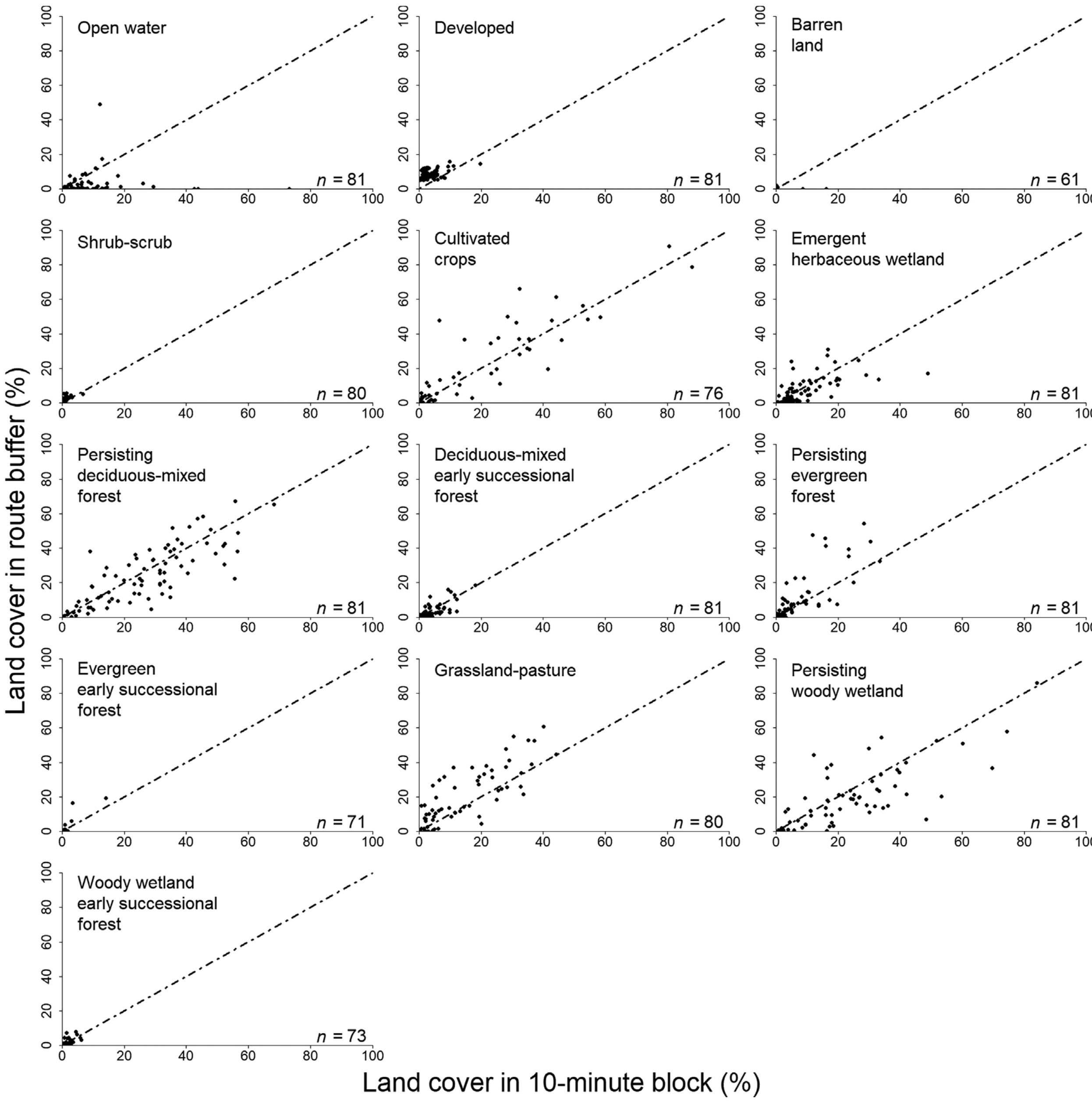

Figure 2. Scatterplots showing percent covers in American woodcock singing-ground survey route buffers against percent covers for 10-minute-degree blocks within the Minnesota, USA portion of Bird Conservation Regions 12 (Boreal-Hardwood Transition) and 23 (Prairie-Hardwood Transition). Route buffers had radii of 330 m, and blocks were simulated to be centered on route midpoints. Dashed lines show expected values based on a 1:1 relationship between percent cover in buffers and blocks. Land cover data nominally represented 2011 and forest age data nominally represented 2009.

Potential causes of unsystematic differences include sampling error or land cover dynamics, such as canopy loss, due to disturbances that are not spatially linked to roads. It is beyond this paper's scope to identify specific causes for the systematic and unsystematic differences observed for cover classes.

By their very natures, rare cover classes have mathematically small ceilings or limits on the magnitudes of percentage point differences observed when comparing route buffers to larger spatial extents. In these instances, small differences can be misleading grounds for claiming that a cover class is well represented by routes. This concern is especially relevant for woodcock because several of its habitat components, including shrub-scrub, deciduous-mixed ESF, and woody wetland ESF, are rare (<5%) in our study region. When we examined relative differences for these habitat components, we found no evidence that they were halved ($\leq -50\%$) or doubled ($\geq 100\%$) in route buffers compared to Minnesota, and we took this as additional support for the claim that route buffers perform well in representing Minnesota. Although in this instance consideration of relative differences did not change our interpretation, we encourage future researchers to consider percentage point and relative differences, especially where species of interest are linked to rare cover classes.

Our study adds to and builds on a growing body of studies that have evaluated the representativeness of SGS routes in

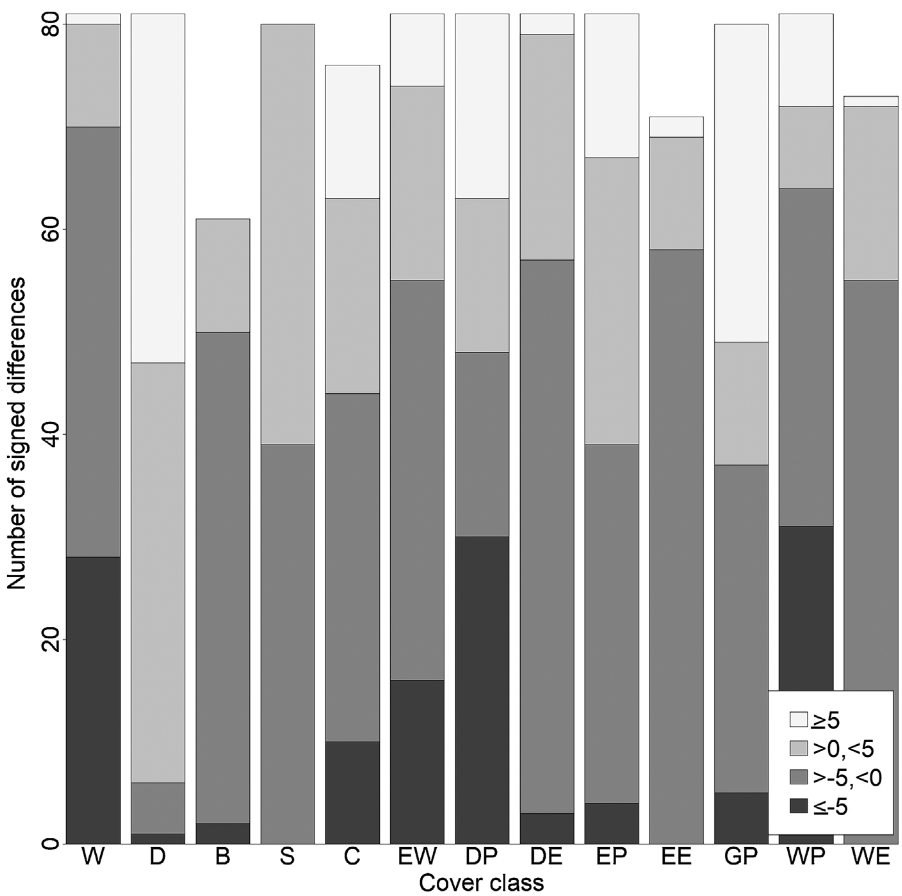

Figure 3. Numbers of signed differences between percent covers of American woodcock singing-ground survey route buffers and 10-minute-degree blocks within the Minnesota, USA portion of Bird Conservation Regions 12 (Boreal-Hardwood Transition) and 23 (Prairie-Hardwood Transition). Route buffers had radii of 330 m, and blocks were simulated to be centered on route midpoints. Cover classes are open water (W), developed (D), barren land (B), shrub-scrub (S), cultivated crops (C), emergent herbaceous wetlands (EW), persisting deciduous-mixed forest (DP), early successional deciduous-mixed forest (DE), persisting evergreen forest (EP), early successional evergreen forest (EE), grassland-pasture (GP), persisting woody wetland (WP), and early successional woody wetland (WE). Land cover data nominally represented 2011 and forest age data nominally represented 2009.

the Upper Midwest (Jentoft 2000, Nelson and Andersen 2013). Jentoft (2000) used broad thematic cover classes, not including ESF, to compare land cover status and trends for routes to the state of Michigan. Jentoft (2000:41) reported that differences between the routes and state were generally <3% and concluded that these differences "...are probably too small to be important in terms of the function of the survey." However, Jentoft (2000:43) also called for future assessments using geospatial data sets better aligned with woodcock habitat, and we used such a data set in our analyses. Based on a 3% threshold of differences reported in Jentoft (2000), we observed that the grassland-pasture habitat component class was over represented by routes relative to Minnesota; however, the difference for this class fell below the 5% threshold from Veech et al. (2012, 2017). For the primary forested regions of Minnesota and Wisconsin, Nelson and Andersen (2013) related open space, ESF (<5 m in height), and mature forest (>5 m in height) to woodcock counts and reported that these 3 land covers did not differ between route buffers and their surrounding landscapes defined as 10-minute blocks. Given these results, Nelson and Andersen (2013:594) concluded "...it is likely that counts resulting from the SGS provide a reasonable source of information for tracking changes in abundance of male woodcock at the landscape scale in the western Great Lakes region." The AWCP definition of ESF includes a structural criterion (small diameter) and an age-based criterion (≤20 years of age). In contrast to Jentoft (2000) and Nelson and Andersen (2013), we could define ESF using spatially explicit forest age data. The fact that Nelson and Andersen's (2013) structural ESF definition and our age-based definition both lead to the conclusion that SGS routes well represent cover classes important to woodcock in Minnesota is reassuring.

Assessments of SGS route representativeness differ in terms of study design and analytical approach (Jentoft 2000, Morrison et al. 2006, Nelson and Andersen 2013, this study). With respect to study design, studies may define the route sample area by buffering around the entire linear path of the route (Morrison et al. 2006, this study) or just the listening points at which singing males are counted (Jentoft 2000, Nelson and Andersen 2013). Route buffers may differ in radius (300 m: Morrison et al. 2006; 330 m: Jentoft 2000, Nelson and Andersen 2013, this study). Route buffer cover classes may be compared to local landscapes (Nelson and Andersen 2013, this study) or to entire states or regions

(Jentoft 2000, Morrison et al. 2006, this study). Analyses may entail simple mathematical comparisons of cover class percentages between route buffers and larger spatial extents (Jentoft 2000, Morrison et al. 2006, this study) or the use of inferential statistics, such as compositional analyses (Nelson and Andersen 2013). To date, no study has deliberately evaluated the influence that these design and analytical differences might have on conclusions about SGS representativeness. Nor have the effects of actual sample blocks, rather than simulated blocks, been explored. We found that the magnitude of differences for individual cover classes changed when comparing route buffers to blocks versus comparing buffers to Minnesota. The same or similar design and analytical differences are present across studies evaluating the representativeness of BBS routes (Keller and Scallan 1999; Betts et al. 2007; Veech et al. 2012, 2017). We encourage future evaluation and comparison of these study designs and analytical approaches.

We assessed the representativeness of SGS route buffers at a single point in time and did not assess whether land cover trends in route buffers reflected trends of local landscapes or regions. Our mapping of forest age depended on a temporally constrained time series (1987–2010) of Landsat satellite images (Garner et al. 2015), so we were unable to produce a time series of ESF that would have enabled a trend analysis. The algorithm we used to derive our forest age maps (Stueve et al. 2011) and other land-cover change detection algorithms are being incorporated into systems for mapping and monitoring United States land cover and land use change through the integration of Landsat-based products and other data sets (Healey et al. 2015). Once these emerging mapping systems become fully operational, their products will offer the opportunity to periodically map forest age classes and to assess the representativeness of land cover trends in SGS route buffers. Such assessments could increase confidence that woodcock trends reported by the SGS reflect trends at larger spatial extents.

Although representativeness has been and will continue to be assessed by researchers, several other challenges face the SGS regarding its design, implementation, and analysis (D.J. Case and Associates 2010). There is an unknown relationship between woodcock counts and true abundance, and the current SGS count protocol does not gather data needed to correct for the imperfect detection of individuals. When examining woodcock occupancy at SGS route listening points, Bergh (2011) reported that detection probability varied based on the presence of conspecifics, observer identity, date, ambient noise, and wind speed. Bergh (2011) proposed several alternative actions to address detection probability, such as repeating surveys on a subset of SGS routes to estimate detection probability or the potential use of call-broadcast surveys to increase detection probability. Unaccounted imperfect detection of individuals could hinder efforts to determine management effectiveness. The implementation of the SGS requires the labor and coordination of many observers, and this can make data collection, verification, and analysis difficult. As an example, we did not analyze SGS route representativeness for Michigan and Wisconsin because observers had not submitted GPS coordinates for all routes, or when coordinates had been submitted, staff resource limitations have curtailed the verification of route locations. Creative solutions, such as crowd-sourcing or otherwise engaging with citizen scientists or local natural resource specialists to assist with spatial data verification, may be required to overcome resource limitations.

MANAGEMENT IMPLICATIONS

Our results support the use of SGS data to assess the effectiveness of ESF creation and management in stabilizing and growing woodcock populations in Minnesota. Our conclusions should not be extrapolated to other scales within this study or to other areas within the woodcock's breeding range. Instead, we recommend that researchers include the methods employed in this study or similar methods to assess the ability of SGS routes to represent their study area of interest and to make comparisons with this study.

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