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LAND COVER ALONG BREEDING BIRD SURVEY ROUTES IN FLORIDA

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Abstract.—The Breeding Bird Survey (BBS) is the most extensive systematic monitoring program for breeding birds in Florida. However, bias associated with different representations of available land cover, may exist in estimates of avian trends derived from roadside counts. Rates of change in land cover along roads also may be different from those within the wider landscape. Six land cover categories (grassland, wetland/open water, scrub/successional, woodland, urban, and other) represented within 400 m of BBS roadside routes (N = 92) in Florida were examined to determine whether they adequately represented land cover within their sample areas. BBS routes appeared to represent their sample areas, and land cover changes along routes from 1985 to 2003 were consistent with those within the sample areas. Mean and median differences were negative for grassland and scrub/successional cover and positive for wetland/open water, woodland, and urban. The mean change for the land cover category designated other was positive, but the median change was 0. Statewide BBS data are likely to provide unbiased trend estimates for birds relative to land cover categories and changes in land cover. Additional BBS routes are needed to sample relatively rare habitats and areas with few roads. Remote sensing was a reliable and cost-effective method of quantifying changing patterns of land cover, and BBS routes should be reassessed when more recent land cover data become available. Local and species-specific studies are needed to detect evidence of habitat fragmentation and to obtain information on the relationship between estimates of avian population trends and changes in land cover.

The North American Breeding Bird Survey (BBS) is a volunteer program initiated by the U.S. Fish and Wildlife Service (USFWS) in 1966 to monitor trends in avian distribution and abundance. The program is managed by the U.S. Geological Survey (USGS) in partnership with the Canadian Wildlife Service. Each BBS route is 39.4 km long, is located on a secondary road, and consists of 50 3-minute counts at 0.8-km intervals. Route locations (starting point and directions) are determined randomly within 1° blocks of latitude and longitude and stratified by state or province. Routes are surveyed by trained observers once annually, during the peak of the breeding season (in Florida, 1 May–15 June). All birds seen or heard at each count point during a 3-minute count period are totaled (Bystrak 1981, Robbins et al. 1986). The survey produces an index of relative abundance, not a complete count of populations. It is assumed that these indices reflect population trends and that consistent survey methods and conditions produce results that are comparable over time.

The BBS is the most extensive systematic monitoring program for breeding birds in Florida. Cox (1987) analyzed Florida BBS data from 19 of 43 routes surveyed from 1969 through 1983 and found 4 species whose populations exhibited strong increasing trends, 15 species with strong decreasing trends, and 66 species that showed no strong trend. Local relative abundances based on BBS results appear to be influenced by habitat availability (Wamer 1978) and habitat changes in Florida (Cox 1987, Hanauer et al. 2010) and elsewhere (Igl and Johnson 1997, Donovan and Flather 2002). Roadside surveys of avian populations, however, may not adequately sample some habitats due to the nonrandom placement of roads and uneven changes in land cover along roads compared with changes across the landscape (Bart et al. 1995, Keller and Scallan 1999, Betts et al. 2007, Harris and Haskill 2007). Consequently, estimated trends in avian abundance obtained from roadside surveys may not be representative of trends within the wider landscape. Evaluating possible bias associated with route representation of its sample area had been identified as an important information need for the BBS (O'Connor et al. 2000, Thogmartin et al. 2006). The objective of this study was to determine whether BBS routes in Florida adequately represented habitats and habitat changes within their sample areas.

Methods

Land Cover Characteristics

The study area was the entire state of Florida as sampled by the BBS (Fig. 1). Digitized location data for BBS routes in Florida were downloaded from the USGS website (http://nationalatlas.gov/mld/bbsrtsl.html). Active and inactive (i.e., discontinued) routes were isolated, and routes with survey data spanning 1985–2003 were identified. Digital land cover data for Florida were obtained from the classification of Landsat 5 Thematic Mapper satellite images (30-m resolution) acquired from 1985–1989 and again in 2003 (Stys et al. 2004). Land cover data derived from Landsat images in 2003 identified 43 classes of natural and human-derived habitats.

Each of the 43 habitat classes in the 2003 land cover dataset was reclassified to represent one of five avian habitat associations (land cover categories) following Peterjohn and Sauer (1993) and one category for other habitats not included in their listing (Table 1). Land cover categories included grassland, water/wetland, scrub/successional, woodland, urban, and other. After reclassification, the land cover data set was generalized using a majority filter that gave each 30- × 30-m cell the most common value of all eight neighboring cells. All spatial analysis was completed using ArcGIS 10.0 (ESRI, Redmond, California).

The land cover data set from 1985–1989 had the same extent and resolution as the 2003 data set but had been classified into only 22 habitat classes. To allow comparison of changes in land cover between the two data sets, we performed a crosswalk to match

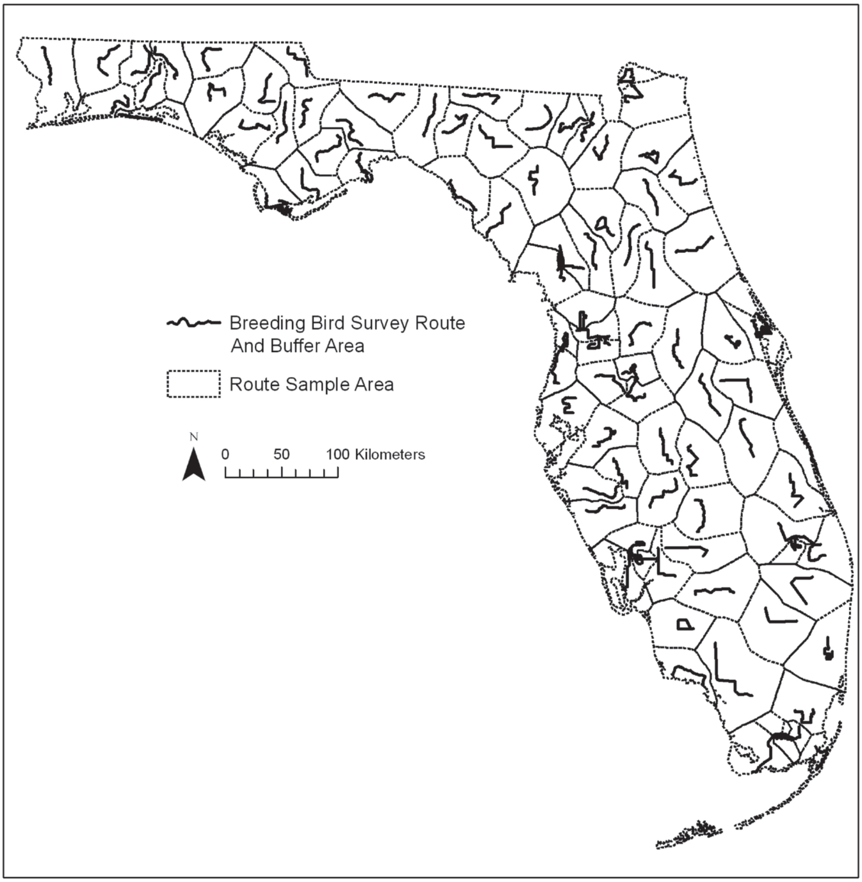

Figure 1. Breeding Bird Survey route locations with buffer areas (N = 92) in Florida from 1985 to 2003, and route sample areas.

1985–1989 habitat classes to the 2003 habitat classes. Most of the 2003 habitat classes were either identical to 1985–1989 classes or were a sub-habitat of the more general 1985–1989 habitats; some 1985–1989 classes, however, had to be converted (Table 1). This conversion was accomplished by assuming that 2003 habitats were also present in 1985–1989 and assigning the detailed 2003 habitat classes to the general classes of the 1985–1989 data. For example, in the 1985–1989 land cover, habitat class *barren* includes lands that actually were barren but also those that were urban. To identify areas that were urban in 1985–1989, we overlaid the 2003 land cover layer indicating urban areas on the 1985–1989 barren areas and reclassified any barren area that intersected the urban area into an *urban* class. This allowed us to estimate change in urban land cover even though the area had not been identified as such in 1985–1989.

Each active BBS route line (N = 92) was buffered by 400 m, the usual maximum distance of birds detected at stops (Robbins et al. 1986), to create a polygon that represented the area surveyed along each route. The total area of each land cover category within the

Table 1. Land cover category (avian habitat association from Peterjohn and Sauer, 1993) and reclassification of 43 habitat classes in Florida from 2003, and 22 habitat classes from 1985–1989 vegetation and land cover datasets. Habitats from 1985–1989 set in normal typeface are directly comparable with those from 2003; classes set in italics are a substitute for the 2003 habitats; classes set in bold italics required conversion before comparisons could be made.

Land cover category	2003 habitat class	1985–1989 habitat class
Grassland	dry prairie	dry prairie
	grassland	grassland (agriculture)
	improved pasture	***grassland (agriculture)***
	unimproved pasture	***grassland (agriculture)***
Wetland/open water	salt marsh	coastal salt marsh
	freshwater marsh and wet prairie	freshwater marsh and wet prairie
	cypress swamp	cypress swamp
	shrub swamp	shrub swamp
	mangrove swamp	mangrove swamp
	open water	open water
	sawgrass marsh	*freshwater marsh and wet prairie*
	cattail marsh	*freshwater marsh and wet prairie*
	scrub mangrove	*mangrove swamp*
	tidal flat	*coastal salt marsh*
	sand/beach	***barren***
Scrub/successional	coastal strand	coastal strand
	sand pine scrub	sand pine scrub
	xeric oak scrub	xeric oak Scrub
	shrub and brushland	shrub and brushland
Woodland	pinelands	pinelands
	sandhill	sandhill
	mixed pine–hardwood forest	mixed hardwood–pine forests

Table 1. (Continued) Land cover category (avian habitat association from Peterjohn and Sauer, 1993) and reclassification of 43 habitat classes in Florida from 2003, and 22 habitat classes from 1985–1989 vegetation and land cover datasets. Habitats from 1985–1989 set in normal typeface are directly comparable with those from 2003; classes set in italics are a substitute for the 2003 habitats; classes set in bold italics required conversion before comparisons could be made.

Land cover category	2003 habitat class	1985–1989 habitat class
	hardwood hammocks and forest	hardwood hammocks and forests
	tropical hardwood hammock	tropical hardwood hammock
	hardwood swamp	hardwood swamp
	bay swamp	bay swamp
	bottomland hardwood forest	bottomland hardwoods
	cabbage palm–live oak hammock	*hardwood hammocks and forests*
	cypress/pine/cabbage palm	***cypress swamp***
	mixed wetland forest	*hardwood swamp*
	hydric hammock	*hardwood hammocks and forests*
Urban	high impact urban	***barren***
	low impact urban	***barren***
Other	exotic plants	exotic plant communities
	Australian pine	*exotic plant communities*
	melaleuca	*exotic plant communities*
	Brazilian pepper	*exotic plant communities*
	bare soil/clearcut	***barren***
	sugar cane	***grassland (agriculture)***
	citrus	***grassland (agriculture)***
	row/field crops	***grassland (agriculture)***
	other agriculture	***grassland (agriculture)***
	extractive	***barren***

buffered area was calculated for 1985–1989 and 2003. To evaluate how well a BBS route represented the surrounding landscape, we used Euclidean allocation to create "route neighborhood" polygons (Niemuth et al. 2007). Route neighborhoods or sample areas represent the area of the state closest to each buffered route (Fig. 1). The total land area of each land cover category within the route sample areas was calculated for 1985–1989 and 2003. Changes in land cover categories were quantified as differences in percentage cover in pixels for both route buffers and sample areas.

Statistical Methods

Statistical tests and graphical summaries were prepared with the R statistical package, version 2.14.2 (R Development Core Team 2012) and with SAS/STAT® version 9.3 for Windows® copyright © 2010 SAS Institute Inc. Differences between 1985 and 2003 in percentage land cover categories for route buffer and sample areas were determined for the 92 BBS routes. Median changes in percentage cover were tested for significance from 0 by the sign test. Chi-square tests were applied to assess significance of difference from a 50:50 split among the routes of positive and negative changes (>0 and <0) within a land cover category. For purposes of display, the differences in percentage land cover were sorted from smallest to largest within each category and then represented as bars in the appropriate direction (positive or negative). Omnibus and pair wise differences in route changes between land cover categories were tested by nonparametric analysis of variance (Kruskal-Wallis rank sum chi-square test). Spearman correlations were determined between route-specific pairs of land cover category changes in the BBS buffer areas and between pairs of land cover category percentages in route buffer areas vs. in route neighborhood sample areas. Because percentages are necessarily constrained (not completely independent), P values and significance statements based on them are intended more as approximate interpretational guides than as exact probability references.

Results

Differences in percentage land cover by category type in 92 route buffer areas from 1985 to 2003 are summarized in Table 2, and sorted bar plots of changes are shown in Figure 2. Mean and median differences were negative for grassland and scrub/successional cover and positive for wetland/open water, woodland, and urban. The mean change for the land cover category designated *other* was positive, but the median change was 0. Normal-based confidence intervals did not span 0 for any land cover categories except for woodland and other, but none of the land cover category change distributions fit normal models well. Interquartile ranges spanned 0 in all cases except for scrub/successional and urban classes. Medians differed significantly from 0 for grassland, scrub/successional, and urban categories.

There was a highly significant omnibus test of heterogeneity among the land cover categories in their degree of change (chi-square = 137, df = 5, $P < 10^{-15}$). Of 15 pair wise comparisons of change in land cover categories, all were highly significant (chi-square ≥15.69, df = 1, $P \leq 10^{-4}$) except grassland vs. woodland (significant at chi-square = 5.29, df = 1, P = 0.02), woodland vs. wetland/open water (chi-square = 0. 82,

Table 2. Summary statistics for differences (2003–1985) in percentage land cover categories in 92 BBS route buffer areas in Florida.

Route buffer land cover	N	Min	LowerQ	Median	UpperQ	Max	Mean	StdErr	LCLmean	UCLmean
Grassland	92	–20.66	–4.77	–0.86#	0.08	18.87	–1.69	0.67	–3.01	–0.37*
Wetland/open water	92	–13.02	–1.47	1.27	3.75	25.72	1.89	0.66	0.58	3.20*
Scrub/successional	92	–36.44	–11.70	–5.74#	–1.55	13.49	–7.48	0.88	–9.24	–5.72*
Woodland	92	–25.63	–3.61	0.05	4.48	26.95	0.97	0.90	–0.83	2.77*
Urban	92	–23.03	1.80	4.92#	8.54	31.59	5.92	0.86	4.22	7.63*
Other	92	–20.67	–3.54	0.00	4.92	30.51	0.51	0.92	–1.31	2.33*

Abbreviations: N = sample size, Min = minimum observed value, LowerQ = lower quartile (25th percentile), Median = 50th percentile), UpperQ = upper quartile (75th percentile), Max = maximum observed value, Mean = mean, StdErr = standard error of the mean, LCLmean = lower 95% asymptotic confidence bound for the mean; UCLmean = upper 95% asymptotic confidence bound for the mean.

#Median significantly different from 0% by sign test.

*Distribution significantly different from normal; confidence limits approximate at best.

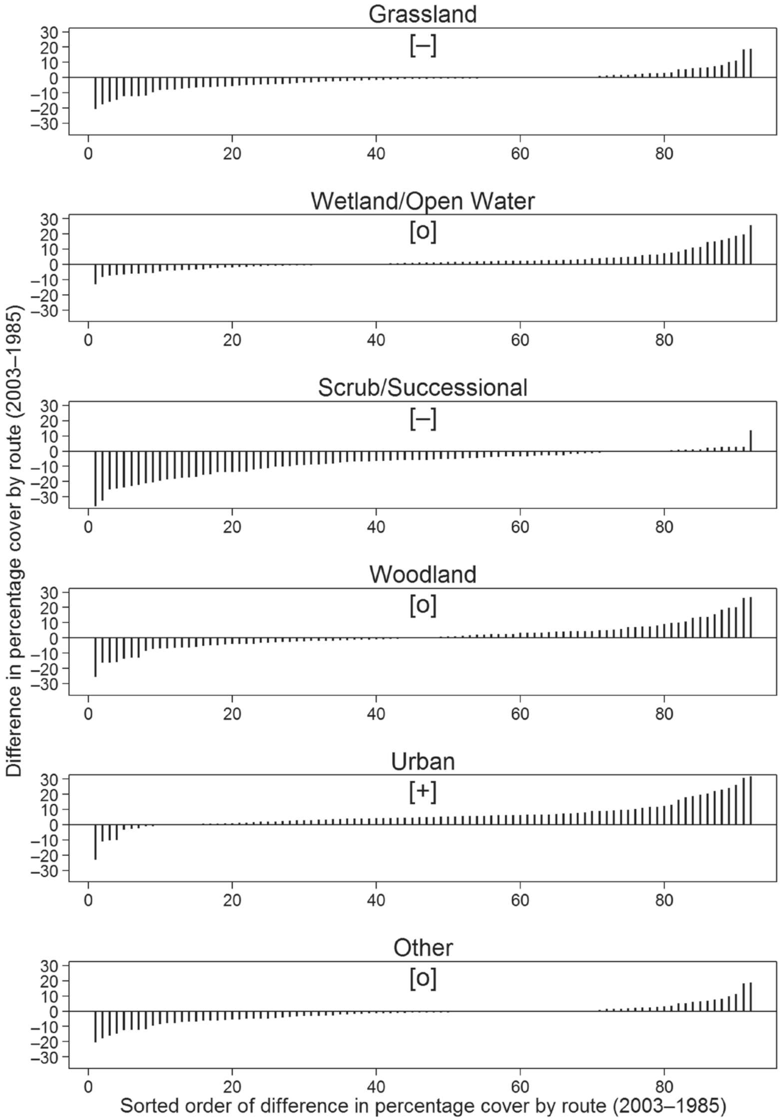

Figure 2. Estimates of differences between 1985 and 2003 in percentage land cover for 400-m buffer areas around 92 individual Breeding Bird Survey routes in Florida, sorted from greatest decrease to greatest increase. Each bar in each plot shows the change estimated for a land cover category on one BBS route. "–" in square brackets indicates that the number of negative changes significantly exceeds the number of positive changes in comparison to a 50:50 split; "+" in brackets indicates that the number of positive changes significantly exceeds the number of negative changes in comparison to a 50:50 split; "o" in brackets indicates that the number of positive changes did not significantly exceed the number of negative changes in comparison to a 50:50 split.

df = 1, P = 0.36), other vs. grassland (chi-square = 3.71, df = 1, P=0.05), other vs. wetland/open water (chi-square = 1.50, df = 1, P = 0.22), and other vs. woodland (chi-square = 0.12, df = 1, P = 0.73). Route changes for grassland, scrub/succesional and urban covers were significantly different from 50:50 positive:negative splits (chi-square ≥ 20.32, df = 1, P = at P ≤ 10^{-5}), whereas those for three cover categories were not significantly different from 50:50: wetland/open water (chi-square = 3.521, df = 1, P = 0.06), woodland (chi-square = 0, df = 1, P = 1.0), and other (chi-square = 0, df = 1, P = 1.0) (Fig. 2).

Although absolute values of correlations between changes for pairs of land cover categories were generally not large, each change in a land cover category for a route buffer was significantly negatively correlated with at least one other category change (Table 3). Correlations were high between changes in land cover categories of the route buffer areas and the route sample areas, and correlations were similarly positive for differences based on the two areas (Table 4).

Discussion

Accurate spatial and temporal information on the status of avian species is needed so that their ability to persist may be evaluated and appropriate conservation strategies determined (Ruth et al. 2003). Roads provide convenient transects that are easily sampled for estimating avian abundance and trends. However, bias may exist in abundance and trend estimates from roadside counts associated with

Table 3. Spearman correlations (r, above in each row) and P(r= 0) between differences (2003–1985) in percentage land cover categories for buffer areas of 92 Florida BBS routes.

	Wetland/ open water	Scrub/ successional	Woodland	Urban	Other
Grassland	−0.28	−0.21	−0.31	0.17	−0.032
	0.01	0.04	0.003	0.11	0.77
Wetland/open water		−0.07	−0.37	0.03	−0.11
		0.52	0.0003	0.75	0.32
Scrub/successional			−0.11	−0.20	−0.42
			0.28	0.06	<0.0001
Woodland				−0.33	0.12
				0.001	0.27
Urban					−0.39
					0.0001

Table 4. Mean percentage cover by land cover category for buffer and sample areas of 92 Florida BBS routes in 1985 and in 2003. Spearman correlations were all significantly different from 0 at $P < 0.0001$.

	1985		Spearman correlations 1985	2003		Spearman correlations 2003	Spearman correlations between differences*
Land cover type	Buffer	Sample area		Buffer	Sample area		
Grassland	14.39	13.16	0.876	12.70	11.10	0.906	0.616
Wetland/open water	16.02	23.05	0.778	17.91	25.20	0.816	0.595
Scrub/successional	13.17	11.19	0.889	5.69	4.67	0.888	0.792
Woodland	36.79	35.82	0.818	37.77	36.92	0.870	0.607
Urban	6.77	6.35	0.683	12.69	10.94	0.533	0.676
Other	12.23	10.05	0.754	12.74	10.82	0.798	0.796

*Correlations between buffer and sample areas with respect to route-specific change (difference) in percentage cover from 1985 to 2003.

different representations of available habitat types and different rates of habitat change within the wider landscape (O'Connor et al. 2000).

Buffer areas around BBS routes in Florida appear to closely reflect composite land cover categories within sampling areas surrounding routes. Estimates of avian population trends should therefore be considered unbiased with respect to changes in habitat availability. The large number of routes (N = 92) in Florida may adequately sample major land cover categories. Large-scale (statewide or physiographic region) analysis of BBS data are not usually subject to large errors caused by environmental misrepresentation (Lawler and O'Connor 2004). Sauer et al. (2003) concluded that the summary of BBS data within North American Bird Conservation Regions (a geographic framework for management plans) appeared reasonable. Analyzing 52 BBS routes in the Northern Plains, Niemuth et al. (2007) found no significant differences between the routes and the route sample areas or "neighborhoods" for upland land cover classes but did detect differences in the representation of deep-water habitat that could bias trend inferences for wetland birds associated with this land cover. In contrast, Harris and Haskell (2007) found a significantly biased representation of land cover along unsurveyed roads and 50 BBS routes in Tennessee compared with land cover proportions of the entire state. Land cover biases changed over time, and simulations of bird trends indicated potential misrepresentation of trends for synanthropic birds and those occupying early-successional habitats sampled by BBS routes (Harris and Haskell 2007).

Studies at a smaller spatial scale evince greater potential bias in avian trend estimates from roadside surveys due to greater discrepancies in land cover between the route and the wider landscape. Examining roadside survey routes at 27 locations in Ohio, Bart et al. (1995) compared land cover at distances of 0–140 m with that at distances of 140–280 m, and with land cover in the surrounding 21 km^2 of the sampling area. They found little bias (<1%) in land cover among areas examined but detected less woodland cover along roads than in the surrounding sample area, which could affect avian trend estimates. A comparison of land cover within BBS route buffers of 200 m and 200–1600 m in Ohio (N = 25) and Maryland (N = 28) found similar differences in land cover at all distances from roads but significantly more urban cover closer to roads in Maryland (Keller and Scallan 1999). Betts et al. (2007) compared variation in the cover of woodland within 150 m of 22 BBS routes to the surrounding 1° block in New Brunswick, Canada, and related changes in woodland cover to a bias in trend estimates of the Blackburnian Warbler (*Setophaga fusca*).

Land cover changes within BBS route buffer areas in Florida from 1985 to 2003 were consistent with those in the route sample areas.

We expected more land cover change along BBS routes than within their sample areas because roadsides are generally more accessible for development. Perhaps land cover along BBS routes was similar to sample areas because of the ubiquity of roads within the landscape.

Relatively rare habitats and areas in Florida with fewer roads (e.g., dry prairie, salt marsh, mangrove forest) are underrepresented by BBS route placement, and land cover changes for these areas were not included in our study. The limited accuracy of Thematic Mapper satellite images may have introduced errors in land cover classification, but these would have been the same for route buffer areas as well as the route sample areas. Our adjustment of land cover categories available from different time periods (1985–1989 and 2003) may also have introduced error (see Kautz et al. 2007). Kautz et al. (2007) examined changes in land cover types in Florida from 1985-89 to 2003 and found an overall decrease in natural and agricultural lands, and a concomitant increase in developed areas. They provide detailed information on the locations and causes of major land cover changes in Florida during our study period.

The projected 90% increase in the conversion of rural land to developed area in Florida by 2030 (White et al. 2009) will almost certainly affect avian population trends. Because land use patterns can change rapidly, BBS route representation of the landscape should be assessed every 5–10 years (O'Connor et al. 2000). Remote sensing was a reliable and cost-effective method of quantifying changes in land cover patterns, and BBS routes should be reassessed whenever more recent land cover data become available. Future assessments should include ground-truthing of land-cover categories and should examine habitat fragmentation along BBS routes and within sampling areas, especially for the scrub/successional and grassland land cover categories. Our results pertaining to the representation of roadside habitats to the wider landscape may apply to the Nightjar Survey Network (see http://www.nightjars.org/), which uses portions of BBS routes to monitor abundance and trends in nightjars; they also may apply to other roadside surveys in Florida such as the North American Amphibian Monitoring Program (Weir and Mossman 2005) and the USFWS Mourning Dove (*Zenaida macroura*) call-count survey (Seamans et al. 2012).

Additional nonrandom BBS routes are needed to better sample dry prairie, salt marsh, and mangrove swamps. This type of route is established to monitor a specific area. Methods can be more flexible than for standard surveys, allowing disjunct count points (>0.8 km apart) and surveys may be conducted on foot or from watercraft. Although results from such routes are not included in the annual USGS analysis of BBS data, these data are available to the public at the BBS website (http://www.mbr-pwrc.usgs.gov/bbs/bbs.html) and can contribute important trend information for local and statewide use. Current (2011) trend estimates for individual species at the statewide level also are available.

Because avian population trends can vary widely across geographic regions (Peterjohn and Sauer 1993), the spatial scale of future studies should be considered. Our land cover data identified large-scale habitat features, but birds also respond to local conditions (Cody 1981, Jones 2001, Johnson 2007) that are difficult to discern with remote sensing. Species-specific studies that include detailed habitat variables and demographic information are needed to determine the relationships between land cover changes and avian population trends.

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