Short Communications and Commentaries

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Reliability of the Breeding Bird Survey: Effects of Restricting Surveys to Roads

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Breeding Bird Surveys (BBS), which are widely used to monitor trends in avian populations (e.g. Robbins et al. 1989, Sauer and Droege 1992), are conducted along roads but are used to infer changes in regionwide populations. Such inferences may be inaccurate if trends in habitat along roads differ from regionwide trends. For example, if forest cover regionwide remained constant but forest cover along roads declined (due for example to development), then BBS data for species found primarily in the forest might show declines despite regional populations being stable. We investigated this issue by measuring change in forest cover in western (i.e. unglaciated) Ohio (Fig. 1). Change in forest cover between 1963 and 1988 was determined for: (a) the complete study area; (b) areas 0 to 140 m from a road (inner roadside strip); and (c) areas 141 to 280 m from a road (outer roadside strip).

Methods.—We attempted to use LANDSAT satellite data for the study, Multi Spectral Scanner (MSS) data from 1972, and Thematic Mapper (TM) data from 1986. We classified the MSS data and used an existing classification of the TM data prepared by the Ohio Department of Natural Resources for their Ohio Wetlands Inventory. We recognized that estimates of forest cover based on satellite imagery were likely to include substantial bias (Dunn et al. 1991, Green 1994), but hoped to use a sample of digitized aerial photographs to correct the bias in the satellite data.

Aerial photographs from the early 1960s and late 1980s were analyzed using methods similar to those of Turner (1987), who studied change in habitat in Georgia during 1937-1983. Photographs from the 1960s were from the Agricultural Stabilization and Conservation Service; those from the 1980s were from the National Aerial Photography Program. A systematic sample (with a random perturbation of each point) of 27 points was selected, and aerial photographs from 1962-1963 (1:20,000; black and white) and from 1988-1990 (1:40,000; color infrared), covering each point were obtained. Each black-and-white photograph covered 21 km^2. Each color-infrared photograph covered 84 km^2, but we used only the 21 km^2 covered by the corresponding black-and-white photograph. Most of the photographs were from 1963 or 1988. Forest cover, defined as land with canopy cover greater than 40% or scrub growth older than 10 years (uncommon on our plots), was digitized in Arc/Info, a geographic information system. Registration was based on five to eight points (road intersections) with known UTM (Universal TransMercator) coordinates. Coverages were converted to GRID format with 20 × 20 m cell resolution. Delineation of the forest cover was checked in the field for six plots. The proportional change in forest cover resulting from these checks was less than 10% in each plot.

Grid coverages were intersected with digital-line-graph (DLG) layers showing roads. These layers were checked for accuracy using topographic maps. The layers were found to include a few limited access highways and private roads, but the total length was less than 3% of the combined length of roads on which BBS routes would occur. No significant changes occurred in the number or location of roads in the study area during our study period, and comparisons between a sample of roads digitized from the aerial photographs and the roads included in the DLG files showed positional errors of less than 20 m for all DLG files. Buffers of 140 and 280 m were constructed on both sides of roads in the sample plots. We judged that most birds vocalizing within 140 m could be detected by BBS observers and that relatively few birds vocalizing at distances greater than 280 m would be detected.

Change in forest cover was expressed in several ways. The proportional change in forest cover, defined as the value in 1988 divided by the value in 1963, was calculated for each zone (inner roadside strip, outer roadside strip, region). The constant proportional change that would produce the observed total change also was calculated for each year, and converted to percent change per year. For example, forest cover 0 to 140 m from roads increased 30% during the 25 years of our study. The equivalent change per year was 1.0105 ($1.0105^{25} = 1.30$), and the percent change per year was 1.05%. This manner of describing change in habitat parallels the approach generally used to described trends in avian populations from the BBS.

Statistical analysis followed Cochran's (1977) discussion of ratios. Change in habitat is a simple ratio (r) of means, so standard formulas (e.g. Cochran 1977: 31) apply. Change per year (c) was calculated as

$$c = r^{0.04}, \qquad (1)$$

and the SE(c), based on a Taylor Series expansion about the true ratio, was $(0.04/r^{0.96})\mathrm{SE}(r)$. Percent change per year was defined as $100(c-1)$, and the SE of percent change per year was 100SE(c).

The variance of the difference between two changes, r_1-r_2, was $V(r_1) + V(r_2) - 2\mathrm{Cov}(r_1,r_2)$, where standard formulas were used for $V(r_1)$ and $V(r_2)$, and $\mathrm{Cov}(r_1,r_2)$ was calculated as explained by Cochran (1977:181) for correlated ratios. The variance of the difference in changes per year was $V(c_1) + V(c_2) - 2\mathrm{Cov}(c_1,c_2)$. The covariance term, calculated from the Taylor Series approximation for r, was

$$\mathrm{Cov}(c_1,c_2) = [0.04^2/(r_1r_2)^{0.96}]\ \mathrm{Cov}(r_1,r_2). \qquad (2)$$

The difference in percent change per year was $100(c_1 - c_2)$, and the SE of this difference was $100\mathrm{SE}(c_1 - c_2)$. Additional notes on the statistical analysis are available from the senior author.

Results.—Efforts to use the MSS data for this study were unsuccessful. The spatial, spectral, and radiometric resolution of the MSS data did not provide sufficient detail. In most areas, we could not identify enough reference points on the image to perform a satisfactory rectification. As a result, positional errors of 160 to 240 m were common, and the nominal roadside buffer frequently missed much or all of the actual roadside area. Furthermore, large areas were misclassified. Residential areas with trees, as well as certain grasslands, abandoned fields, scrubgrowth, and other areas, often were classified as forest. Forests, and especially small woodlots in agricultural areas, often were classified as nonforest. Possibly MSS could be used for regionwide comparisons, but we suspect a substantial effort would first be needed to prepare the classification, obtain error estimates from a sample of aerial photographs, and use these estimates to statistically correct the classification results.

Results with the TM data were somewhat better (Table 1). We analyzed 10 plots, comparing the entire 84 km^2 on each color-infrared photograph to TM data for the same area. Overall accuracy was high, about 94% (0.05 + 0.89 from Table 1). Percent error, defined as 100 ([estimated amount/actual amount] − 1), varied from 0 to 50% (Table 2, Fig. 2).

TABLE 1. Classification accuracy achieved using TM satellite data to delineate forest and nonforest cover. Entries are average proportions of areas in 27 sample plots.

	Classified as		
Actual cover	Forest	Nonforest	Total
Forest	0.05	0.02	0.07
Not forest	0.04	0.89	0.93
Total	0.09	0.91	1.00

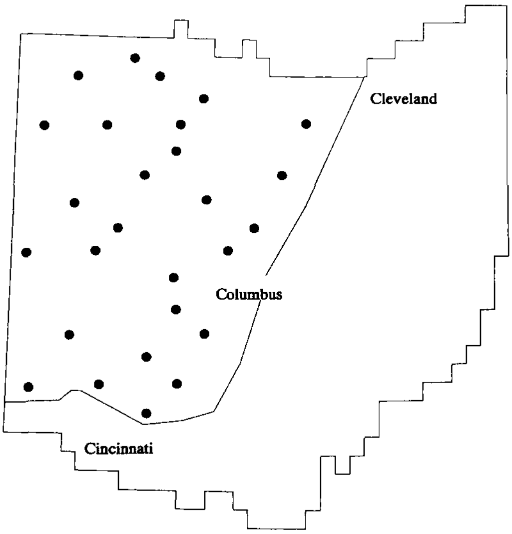

Fig. 1. Locations of sample plots in Ohio.

Analysis of the aerial photographs indicated that forest covered 6.95% of the region in 1963 (Table 3). By 1988, regionwide forest cover had increased by 17% to 8.14%, a small but statistically significant increase ($P < 0.001$). The 25-year change is equivalent to an annual proportional increase of 0.64% per year.

Forest cover along the roads in 1963 was less (4.08%) on the inner strip, but about the same (6.22%) on the outer roadside strip, as for the entire study area (Table 3). By 1988, forest cover along the roads had increased about 30% on both the inner and outer strip. Forest cover in the inner strip was significantly smaller than the regionwide values in both 1963 and 1988 on the inner strip but not on the outer strip (Table 3).

TABLE 2. Accuracy of forest cover map delineated using TM data for Ohio.

Plot	Amount of forest		Percent
no.	Estimated	Actual	error
1	0.05	0.04	25
2	0.07	0.06	17
3	0.23	0.16	44
4	0.05	0.04	25
5	0.09	0.08	13
6	0.23	0.21	10
7	0.12	0.08	50
8	0.03	0.02	50
9	0.02	0.02	0
10	0.04	0.04	0
$\bar{x}$	0.093	0.075	23

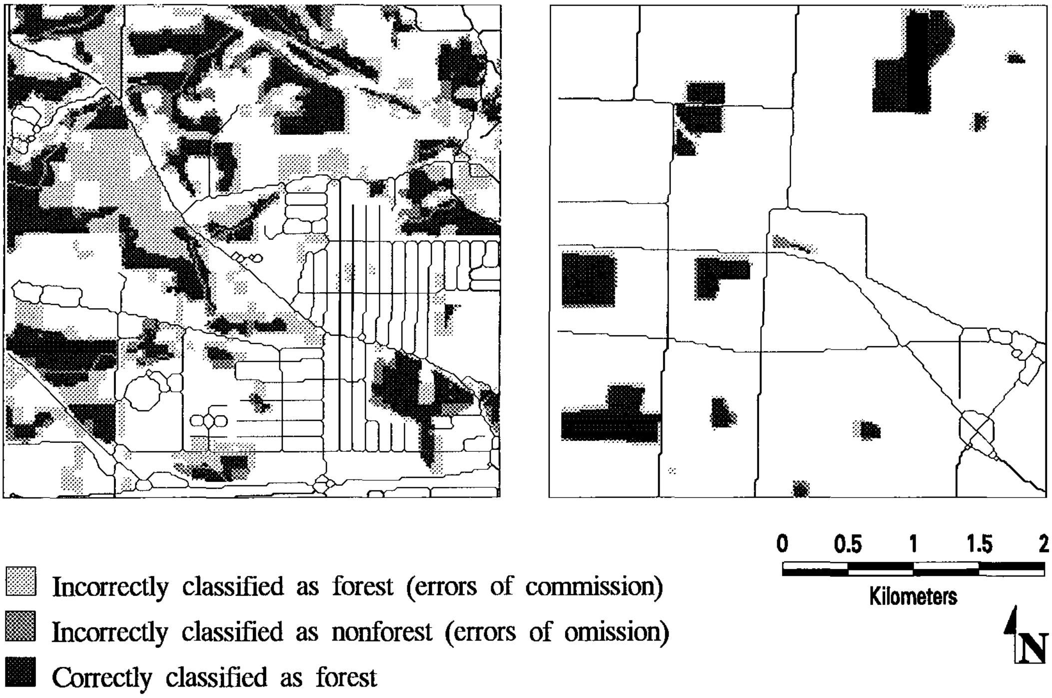

Fig. 2. Comparison of forest cover depicted from aerial photography and TM imagery: (left) plot showing poor agreement; (right) plot showing good agreement.

The increases in forest cover along roads (either 0 to 140 m from roads or 141 to 280 m from roads) were about the same as the regionwide trends. Expressed as annual percent changes, the values were 1.05% for the inner strip, 1.11% for the outer strip, and 0.64% for the region (Table 4). These values are within 0.5% of each other, and they were not significantly different (Table 3). The standard error of the difference (inner strip minus region) was 0.32, so the 95% confidence interval for that difference would be about 0.4 ± 0.6%, or −0.2 to 1.0%. Thus, the trends in habitat along the inner roadside strip and throughout the study area were probably (i.e. with 95% certainty) within 1% of each other. Similar calculations for the difference between the outer strip and the region (i.e. outer strip minus region), yield a 95% confidence interval for that difference of 0 to 1%. Thus, those trends, measured across the entire study area, also were probably within 1% of each other. It can also be shown (Bart unpubl. manuscript) that bias in estimates of avian population trends would be 1% or less, and far less than 1% for nonforest species.

Discussion.—In our study area, the bias in estimates of percent change per year caused by differences in habitat trend between roadside areas and the entire region was small and almost certainly less than 1%. This result is reassuring for those using BBS data to make inferences about temporal trends in regional populations, but the analysis should be repeated in other regions and with a more detailed habitat classification.

The level of accuracy we obtained from analysis of the TM data would be considered acceptable for many applications. For example, in a study of forest cover

TABLE 3. Estimates of average forest cover (±SE) and of temporal change in forest cover (±SE) along roads and throughout study area in western Ohio.

Variable	Roadside strips		Throughout study area
	0–140 m	141–280 m	
Percent forest cover in 1988	5.29 ± 0.90	8.19 ± 1.36	8.14 ± 1.21
Percent forest cover in 1963	4.08 ± 0.60	6.22 ± 0.93	6.95 ± 0.97
Ratio (1988/1963)	1.30 ± 0.08	1.32 ± 0.07	1.17 ± 0.06
Percent change/year	1.05 ± 0.26	1.11 ± 0.22	0.64 ± 0.19

TABLE 4. Average differences (±SE) in forest cover and in change in forest cover along roads and throughout study area in central Ohio.

Difference in	Inner roadside strip vs. entire study area	Outer roadside strip vs. entire study area
Forest cover 1988	−2.85 ± 0.58**	0.05 ± 0.43
Forest cover 1963	−2.87 ± 0.52***	−0.73 ± 0.53
Ratio (1988/1963)	0.13 ± 0.10	0.15 ± 0.08
Percent change/year	0.41 ± 0.32	0.47 ± 0.24

***, $P < 0.001$; all others $P > 0.05$.

[a] For t-test of null hypothesis that true difference is zero.

in Minnesota, Bauer et al. (1994) achieved 86% accuracy in classifying forest versus nonforest. In our study, however, reliance on the TM imagery for the 1988 estimates would have led to substantial errors. The TM classification suggested that forest cover in the entire area covered by the color-infrared photographs averaged 9.3%, whereas the true value, determined from the photographs, was 7.5% (Table 2). Thus, the TM classification overestimated forest cover by about 24%. Had TM analysis been used to estimate forest cover on our plots, the estimates would have been about 24% higher in each zone in 1988. If we increase the 1988 forest-cover values (in Table 3) by 24% and then calculate change in forest cover from 1963 to 1988, the estimates (vs. true values) for inner roadside, outer roadside, and regionwide zones become 59% (vs. 30%), 62% (vs. 32%), and 44% (vs. 17%), respectively. This analysis assumes that each estimate would have been exactly 24% higher, whereas the change actually would have varied due to sampling error. Thus, use of the TM data would have caused substantial errors in forest cover and change in forest cover along roads and throughout the region.

Numerous land-cover classifications are available or under development. Our experience indicates the value of carrying out formal error analyses, including calculations of bias in the quantities being estimated, before using land-cover classifications.

The absolute amount of forest cover in 1988 in the zone of 0 to 140 m from roads was 35% lower than the regionwide value (5.29 vs. 8.19%), a result that is not surprising, but shows the difficulty in using BBS data to portray abundances of species across their range. For example, consider a forest species whose range included our study area and some other area with about the same amount of forest cover. Assume further that, in this other area, forest coverage was similar along roads and regionwide. In such a case, BBS results would be 50% higher (8.19 vs. 5.29%) in this other area than in our study area due solely to the difference in how forest cover was distributed.

No other studies have addressed this issue, so it is difficult to put upper limits on the bias in estimates of relative abundance that might be caused by differences in distribution of habitat. In the absence of other information, one must probably regard maps of relative abundance as suggestive, but susceptible to biases of unknown magnitude.

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