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POTENTIAL ROADSIDE BIASES DUE TO HABITAT CHANGES ALONG BREEDING BIRD SURVEY ROUTES[1]

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Abstract. Breeding Bird Surveys (BBS) are conducted along roadside routes to enable a large geographic area to be surveyed. Yet the potential biases of sampling populations only from roadsides have received little attention. We sampled aerial photography of BBS routes taken in the mid-1960s and late-1980s to evaluate whether habitat changes that occurred along roadsides were also occurring in the surrounding area, and whether the frequency of habitats encountered along roadsides were similar to that off-route. We examined 28 routes in Maryland and 25 routes in Ohio, and defined roadside area as within 200 m of the road, and off-route as 200–1,600 m from the road. Most habitat changes that occurred along BBS roadsides also were occurring in the off-route areas. However, increases in urban cover were significantly greater along the road in Maryland where urbanization of farmland was the predominant habitat change. The small increase in urban cover in Ohio was not significantly greater along the road. Construction of single family homes was greater along BBS roadsides in both states. In Ohio, the greatest change in habitat was the conversion of farmland back to forest, which was not significantly greater along the road. Changes associated with urbanization were more biased towards roadsides than the reforestation of farmland. Within one time period, roadside areas had less forest and more agricultural and urban cover types than occurred off-route.

Key words: BBS, Breeding Bird Survey, habitat change, roadside bias, roadside habitats, roadside surveys.

INTRODUCTION

The North American Breeding Bird Survey (BBS) was initiated in the mid-1960s to monitor the distribution and abundance of bird populations throughout the United States and Canada (Robbins et al. 1986, Droege 1990). The survey is conducted along secondary roads, randomly selected within degree blocks of latitude and longitude. Each BBS route is 40-km long and consists of 50 point-counts spaced 0.8 km apart. There are over 4,000 routes distributed across North America, making the BBS one of the most extensive wildlife surveys in existence. The broad geographic coverage of this survey would not be possible without the use of roads.

The BBS is the primary source of population trend information for a large number of North American bird species (Robbins et al. 1986, Robbins et al. 1989, Sauer 1993) and has been used to rank species and determine which are most in need of conservation effort (Hunter et al. 1993, Smith et al. 1993). There has been considerable work on improving various aspects of BBS trend analysis (Robbins et al. 1986, Geissler and Sauer 1990, James et al. 1990) and eliminating potential biases resulting from different observers (Sauer et al. 1994) and the increased experience of observers over time (Kendall et al. 1996). However, there has been very little evaluation of the potential biases of sampling populations of birds exclusively from roads.

One important concern is that roadside habitats might be changing in different ways or at different rates than off-road areas. If so, the trends in bird numbers sampled exclusively from roads might not reflect the trends in bird numbers occurring across the entire landscape. Roads provide access to the land by people, thus residential and commercial development is more likely to occur along roads. Clearing of forested landscapes generally begins along roads which are built for timber harvest, resulting in clearcuts

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adjacent to roads and forest away from the road (Sader and Joyce 1988). The concentration of forest clearing and commercial development along roadsides could mean that bird populations near roads experience greater rates of habitat change than are occurring in the entire landscape. These same concerns could affect other roadside surveys such as national surveys for American Woodcock (*Scolopax minor*) and Mourning Doves (*Zenaida macroura*) (Dolton 1993, Straw 1993).

A second potential bias of sampling bird populations from the road is that roadsides probably do not provide a complete or representative sample of the habitats in an area and their corresponding bird community because the placement of roads in the landscape is not random. For example, Droege (1990) points out that in the West, roads often are constructed in stream valleys and consequently oversample riparian habitat, whereas in non-mountainous regions, roads tend to cross riparian forests and undersample these habitats. More edge species may be detected from roadside points than from off-road points because of the habitat edge always associated with roads (Keller and Fuller 1995), and some species may be missed by roadside counts if they are associated with wetland habitats not often located near roads (Hanowski and Niemi 1995a). This sampling bias may not affect estimates of population trends, but it is more important when trying to use roadsides to obtain a complete survey of all species in a National Forest or National Park (Hanowski and Niemi 1995b).

Bart et al. (1995) conducted the first examination of the potential habitat biases of sampling from roads. They compared changes in forest area within 140 m of a road, 140–280 m from a road, and in the surrounding 21 km^2 region, from 27 random locations in western Ohio. There was no significant difference in the changes in forest area occurring in the roadside, near-road area, and surrounding region. However, their study only examined forest cover in western Ohio. A more complete picture is needed of how all habitat types might be changing, specifically along the BBS routes themselves.

In this investigation we used aerial photography of BBS routes from the mid 1960s and late 1980s to compare how habitats changed in a 25-year period along BBS roadsides and in the surrounding area. The surrounding areas are not completely roadless, and a random sample of most landscapes will include some roads. But a sample that is constrained to roads may not reflect the changes occurring in the landscape in general. Our objectives were to (1) describe and compare the change in habitats over a 25-year period along BBS roadsides to the habitat changes that have occurred in the surrounding landscape, and (2) compare the frequency of both large and small habitat components between BBS roadsides and the surrounding areas within the same time period, in order to quantify which habitats are most likely to be sampled from roadside routes.

METHODS

We compared land use and habitat changes along BBS routes in Maryland and Ohio. These states were chosen because they have a high density of routes and different patterns of land use change. Proximity allowed us to ground-truth our habitat classification on Maryland routes. The Forest Service estimated that between 1962 and 1987, there was a decrease of 155,400 ha of timberland in Maryland (6% of the land area) and an increase of 445,156 ha in Ohio (4% of the land area) (Waddell et al. 1989). Ohio had the second greatest increase in forest area among all states; only New York was higher. We felt it was important to make our assessments of roadside biases in states with different patterns of land use change.

We selected routes from each physiographic area of each state and attempted to spread out the sample geographically. The following provides the physiographic region of the state, and the number of routes sampled in the region (also expressed as the percentage of the total routes available in the region in 1990): Maryland—Allegheny Plateau, 3 (100%); Ridge and Valley, 3 (100%); Northern Piedmont, 13 (65%); Upper Coastal Plain, 19 (63%); Ohio—Great Lakes Plain, 3 (43%); Allegheny Plateau, 3 (43%); Ohio Hills, 9 (64%); Till Plains, 8 (42%); Lexington Plain, 2 (66%).

Some routes were not selected because the photography was not complete for both years, or it overlapped geographically with a route already in the sample, or it had only been surveyed a few years. We were able to obtain complete imagery for 25 Ohio BBS routes and 28 Maryland routes. We obtained imagery for the area within 1.6 km of each route from the early

1960s and late 1980s, primarily 1963 and 1988 (75% were within one year of 1963, and 98% were within one year of 1988). We will refer to these as the early and late photography, respectively. Imagery was purchased from the Agricultural Stabilization and Conservation Service, Salt Lake City, Utah (currently part of the Natural Resources Conservation Service). Early photography was 1:20,000 scale black-and-white imagery; late photography was 1:40,000 scale black-and-white imagery projected at a scale of 1:20,000.

We defined the area within 200 m of the road as "on-road" or "roadside" habitat and considered this to be the area where most birds are detected on BBS routes. Habitats beyond 200 m can influence the species detected from the road, but we expected changes in roadside habitats to have the greatest influence on populations of birds detected from BBS routes. We defined the "off-route" or "surrounding" area as the area greater than 200 m but less than 1,600 m from the road. This is the landscape around the BBS road and can include some roads. We sampled aerial photography of both the roadside area and the off-route area using randomly selected cells in a grid overlaid on the aerial photographs.

DATA COLLECTION

A photo-mosaic of each route area was constructed using the most recent photography, and an acetate overlay with a 4-ha grid (1 cm^2 at a scale of 1:20,000) was placed over the mosaic. Samples of 100 grid-cells were randomly selected in both the roadside and off-route areas. Samples were stratified so that 50% of each sample was on each side of the road. The same grid cells were then located on the photo-mosaic of the 1963 photography. These mosaics were placed side-by-side to ensure that the locations of the sample grid cells were identical on the two photo-mosaics and that any habitat changes would be clearly visible.

The habitat in each sample grid cell was visually classified by the predominant land cover of the cell (for example cropland, forest, or urban). Smaller habitat features in the grid cell that occurred as points or lines also were recorded. These are habitat features that are not likely to cover an area of 4 ha, but are often important for birds, for example hedgerows of shrubs and trees, small ponds, or the presence of a house, farmyard, or barn. We counted the number of each of these features present in the cell. This system of recording the cell cover type and point and line habitat features enabled us to assess the frequency of both small and large habitat components with one sampling scheme.

CLASSIFICATION SYSTEM

Our habitat classification scheme was based upon the land use and land cover classification system developed by Anderson et al. (1976), and used by the U.S. Geological Survey. It is a hierarchical system, and we used their first and second level classifications with some modifications. Anderson et al. (1976) define forest cover as land with a tree-crown cover of 10% or more, which includes clearcuts and parkland. We subdivided forest into 3 classes based on crown closure of trees as follows: forest—crown closure of 50–100%, early forest—25–50% crown closure, and early successional land—10–25% crown closure. We defined old field as grassland having less than 10% canopy cover of trees; this cover type could occur in abandoned cropland or parks. The data were collected using more cover types and modifiers than are reported here, but those that were very rare or on less than half of the routes were not included in these analyses (for example, gravel pits, plantation forest). Modifiers also were combined if individual occurrence was low, for example, shrub rows and tree rows were combined to shrub and tree rows. We report results for 6 habitat cover types and 12 habitat features.

DATA ANALYSIS

For each route, the frequency of habitat cover types and features was recorded for 100 grid-cells along the BBS roadside and 100 grid-cells in the off-route area in both the early and late photography. Habitat changes for the route were simply calculated as the difference in the frequency of each habitat cover type or feature between the late and early photography in the roadside or off-route area.

To determine whether the habitat changes between 1963 and 1988 in the roadside area were the same as those occurring off-route, we used a paired-sample t-test comparing the change in frequency of each cover type in the roadside area to the change in the off-route area. To assess whether roadside habitats are representative of those found off-route, we used a paired-sample t-test comparing the frequency of habitats on-road to their frequency off-route within the same year.

Although each of these comparisons evaluates different potential roadside biases, they involve use of the same data in several analyses, and thus increase the opportunities for Type I errors. Rather than adjust the probability levels, we have chosen to report the calculated *P*-values, understanding that our use of these statistics is to highlight certain habitat types that may change differently along the road than off-route.

We report the mean frequency of habitat cover types and features along these BBS routes. Mean frequency of a cover type, for example, agriculture, is the mean number of grid-cells classified as agriculture from a sample of 100 grid-cells. Because our sample is 100 grid-cells, it also is the mean percent of a sample classified as agriculture. The mean frequency of a habitat feature, such as houses or ponds, is the mean number observed in a sample of 100 grid-cells (400 ha area).

RESULTS

DESCRIPTION OF ROUTES

The most frequent cover type along both Ohio and Maryland BBS routes was agriculture (Table 1). In Ohio in 1963, roadside areas had 80% of a sample classified as agriculture, approximately 10% of the sample was forest, and 3% urban. In Maryland in 1963, 60% of the roadside samples were classified as agriculture, 32% were forest, and approximately 5% urban. Habitat features associated with farmland, such as hedgerows and farmsteads, were more common in Ohio, and those associated with more urban areas, such as houses, highways, and roads, were more frequent in Maryland.

The general pattern of habitat changes along BBS routes in these two states was very different. Considering both the on-road and off-route samples, Ohio routes were generally changing from agricultural cover to forest cover. This pattern occurred on 23 of 25 routes, and ranged from 0 to a 16% increase in forest cover among routes. However, the predominant change along Maryland routes was an increase in urban cover and decrease in agriculture in both the on-road and off-route area. This pattern occurred on 24 of the 28 routes. The degree of urbanization varied considerably among routes. The greatest increases occurred on two routes that had a 32% and 40% increase in urban cover in the combined on-road and off-road areas, but 16 of the 28 routes had less than 2% increase in urban cover.

COMPARISON OF ROADSIDE AND OFF-ROUTE HABITAT CHANGES OVER TIME

In Ohio, there were no differences in the way cover types changed over time between the roadside and off-route areas (Table 1). Both the roadside and off-route areas had small increases in the frequency of urban cover (1.5% and 1.1%, respectively), substantial decreases in the frequency of agricultural cover (7.6% and 6.3%, respectively), and increases in the frequency of forest cover (4.1% and 2.7%, respectively). However, several habitat features had different rates of change between roadside and off-route areas. Roadside areas had greater increases in the frequency of single-family homes and nonresidential buildings than off-route areas. In the off-route area, there was a greater increase in the frequency of rivers, streams, and ditches because of an increase in agricultural ditches off-road. With these three exceptions, temporal changes in habitat features in roadside and off-route areas were very similar in Ohio.

Between 1963 and 1988 in Maryland, both the roadside and off-route areas had an increase in the frequency of urban cover and a decrease in the frequency of agricultural cover, but these changes were significantly greater in the roadside area (Table 1). Over time, roadsides averaged 7 more cells classified as urban, while off-route areas had 5.6 more cells. This difference is not large, but greater urbanization was seen in roadside areas on 16 routes, and in off-route areas on only 5 routes. Remaining routes had no change or no differences in urbanization in the two areas. On-road areas averaged 7.5 fewer cells classified as agriculture; off-route areas averaged 5.0 fewer cells (Table 1). As seen along Ohio routes, there was a greater increase in the frequency of single-family homes in the roadside areas versus off-route areas (12.5 new homes per sample versus 5.2 new homes per sample, respectively).

COMPARISON OF ROADSIDE AND OFF-ROUTE HABITATS AT ONE POINT IN TIME

In 1963, both Ohio and Maryland roadside areas had a greater frequency of urban and agricultural cover types and lower frequency of forest cover

TABLE 1. Frequency of habitat cover types and features on-road and off-route in 1963, and mean change in the frequency from 1963 to 1988. Frequency of cover types is the mean number of grid-cells (out of 100 possible cells) classified as that type. Frequency of habitat features is the mean number of features found in a sample of 100 grid cells. Positive values indicate the frequency of the cover type or feature increased over time; negative values indicate a decrease over time.

	Ohio					Maryland				
Habitat	No. of routes	Mean frequency on-road 1963	Mean frequency off-route 1963	Mean (SE) change in frequency on-road 1963–1988	Mean (SE) change in frequency off-route 1963–1988	No. of routes	Mean frequency on-road 1963	Mean frequency off-route 1963	Mean (SE) change in frequency on-road 1963–1968	Mean (SE) change in frequency off-route 1963–1988
Habitat cover types										
Urban	18	2.9	0.8**,[a]	1.5 (0.4)	1.1 (0.4)	25	5.4	3.5**	7.0 (2.1)	5.6 (1.9)*
Agriculture	25	80.2	69.3***	−7.6 (1.3)	−6.3 (1.1)	28	59.2	50.3***	−7.5 (1.4)	−5.0 (1.4)**
Forest	25	10.1	19.6***	4.1 (1.0)	2.7 (0.9)	28	31.8	40.2***	−0.1 (1.1)	−1.0 (1.4)
Early forest	24	2.9	4.9*	2.5 (0.9)	2.7 (1.0)	28	1.5	1.7	0.8 (0.4)	0.4 (0.6)
Early succession	21	1.9	1.7	0.0 (0.4)	0.3 (0.4)	22	0.6	0.7	0.3 (0.3)	0.3 (0.3)
Old field	22	2.5	3.3	0.0 (0.7)	−0.5 (0.4)	20	0.8	1.2	0.2 (0.3)	0.2 (0.5)
Habitat features										
Single family homes	25	19.2	4.6***	7.4 (1.8)	2.6 (0.6)**	28	29.8	10.1***	12.5 (3.7)	5.2 (2.0)**
Farmsteads	25	9.2	3.2***	−0.3 (0.4)	0.0 (0.2)	28	7.2	4.0***	−1.4 (0.5)	−0.7 (0.3)
Non-residential buildings	24	2.6	1.0**	1.6 (0.4)	0.4 (0.2)**	26	3.9	1.8**	1.6 (0.7)	0.9 (0.4)
Highway	20	0.9	1.6	0.4 (0.4)	0.5 (0.2)	26	1.6	2.4	0.9 (0.3)	0.9 (0.7)
Secondary road	25	10.3	13.2*	0.8 (0.3)	1.0 (0.4)	28	7.8	11.4**	1.5 (0.5)	2.0 (0.7)
Farm road/driveway	25	13.5	13.3	1.4 (0.9)	2.6 (1.1)	28	25.3	25.3	2.7 (2.3)	4.7 (1.8)
River, stream, ditch	25	11.5	10.2	4.0 (0.9)	7.8 (1.8)*	22	5.2	8.7	2.4 (0.5)	1.5 (0.8)
Lakes and ponds	25	2.4	1.8	2.2 (0.5)	1.7 (0.6)	21	1.1	1.0	1.0 (0.3)	1.0 (0.3)
Small impoundments	16	0.9	0.6	0.7 (0.2)	0.4 (0.2)	17	0.4	1.2	0.7 (0.2)	1.5 (0.4)*
Shrub and tree rows	25	27.2	24.8	−3.4 (1.5)	−3.1 (1.5)	28	19.2	22.3	−2.5 (1.3)	−1.5 (1.9)
Sharp forest/field edge	25	13.4	23.1***	0.6 (1.2)	−2.0 (1.7)	28	24.4	33.1	−2.2 (1.6)	−3.2 (1.3)
Gradual forest/field edge	25	13.9	15.2	−1.2 (1.0)	−4.0 (1.2)	28	8.8	9.3	−0.4 (0.8)	0.1 (1.1)

[a] *t*-test comparison was different (* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$).

types than the off-route areas (Table 1). Analysis of 1988 data was very similar and is not presented here. In Ohio, there was a 11% greater frequency of agricultural cover in roadside samples versus off-route samples. Even more dramatic differences occurred with single family homes. In the 1963 photography of Maryland routes, there was a mean of 19 more homes in the roadside sample versus the off-route sample. By 1988, this difference had grown to 27 more homes in a roadside sample than in an off-route sample. The differences in the frequency of these habitat features in the 1963 photography (Table 1) suggest that the clearing of land for agriculture and the construction of urban areas and homes had been concentrated along roads for a long time prior to 1963.

DISCUSSION

These results suggest that most habitat changes within 200 m of BBS roadsides parallel the habitat changes occurring in the landscape within 1,600 m of the route, but changes associated with urbanization are likely to be more dramatic along the road. Increases in urban cover were significantly greater along the road in Maryland where urbanization of farmland was the predominant habitat change. The small increase in urban cover in Ohio was not significantly greater along the road, most likely because the (1.5%) increase was too small to detect a roadside bias (Table 1). Between 1980 and 1990, Maryland's population increased by 13.4%, while Ohio's increased by only 0.5% (U.S. Bureau of the Census, web:www.census.gov, May 1998). Construction of single family homes was greater along the BBS roadsides in both states. It is reasonable to expect that new homes would be concentrated along the road where access to the land is easiest. In Ohio, the greatest change in habitats was the conversion of farmland back to forest, and this was not significantly greater along the road. This was somewhat surprising considering that roadsides have more farmland than off-road areas (Table 1). It appears that changes associated with urbanization are more biased towards roadsides than the reforestation of farmland.

Bart et al. (1995) reported similar results regarding changes in Ohio forest. From 27 random sampling points in Ohio, they found there were no differences in the extent of the forest increase that occurred along roads, near roads, and throughout the surrounding area. As in our study, they found roadside strips had less forest cover than the surrounding areas in both 1963 and in 1988. In their study, roadside strips were not located specifically on BBS routes but on any road in the scene. They also measured the total area of forest on aerial photography, rather than sample the frequency of forest and other habitat types, as we did. The similar results from these two different methods increases our confidence that the habitat changes we detected are real.

The differences between roadsides and off-route areas observed in this study certainly do not suggest that we abandon roadside surveys. The advantages of surveying from the road include greater sample sizes and greater continuity of surveys, which are very important in the surveys' ability to detect trends (Cox 1990). Even if roadsides are experiencing greater rates of urbanization, the direction of these changes is the same in the surrounding landscape. For example, if the abundance of a species was directly and only related to the abundance of single-family homes, then BBS surveys might over-estimate a population increase in that species. However, its population would be increasing in the surrounding area as well, just not as fast. The most difficult problem would occur if roadsides changed in the opposite way as the surrounding landscape. In the Ohio and Maryland routes we studied, this did not occur for any habitat type or feature. It would be useful to examine potential roadside bias in an area that is more influenced by timber harvest or the conversion of forest to agriculture, to obtain a more complete picture of possible roadside bias associated with different types of land use changes.

We believe one of the biggest strengths of this study is a classification scheme that enabled us to sample the frequency of habitat cover types and smaller point and line features at the same time. It is important to determine potential roadside biases of habitat features that might be related to bird distribution and many of these are not large enough to be considered cover types. For example, hedgerows and single-family homes might influence the abundance of several species, but these are too small or narrow to be included when delineating cover types, and most studies of large areas do not include these features (Dwyer et al. 1983, Scott et al. 1993, Hepinstall and Sader 1997). Whether these features ultimately are related to any species' population trend remains to be seen, but quantifying the abundance of small features over large areas may be necessary.

The challenge facing many scientists and managers is finding habitat features, discernable using remote sensing, that are useful in predicting a species' occurrence or trend over large areas. There has been some success with a few of the large wildlife-surveys. For example, Dwyer et al. (1983) found that increases in urban cover along American Woodcock survey routes was correlated with population declines detected by the call-count index. Hepinstall and Sader (1997) had some success in developing predictive models of species occurrence using BBS data and Thematic Mapper satellite imagery.

Temple and Wiens (1989) concluded that although it is important to monitor bird populations in order to conserve them, determining the cause of population trends is extremely difficult because of the many factors that can influence trends in a population. This is still true, but a better understanding of the habitat changes along the routes where birds are surveyed may help give some indication of the influence of local habitat changes on bird population trends.

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