Research Article

Uneven Rates of Landscape Change as a Source of Bias in Roadside Wildlife Surveys

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ABSTRACT Roadside survey data have been used frequently to assess species occurrence and population trends and to establish conservation priorities. However, most studies using such data assume that samples are representative of either the amount of habitat or its rate of change at larger spatial scales. We tested both of these assumptions for the Breeding Bird Survey (BBS) from 1974 to 2001 in New Brunswick, Canada. Our study focused on mature forest—a cover type that we predicted would be characterized by rapid change due to human activities and that is of high ecological importance. We also sought to determine whether land cover changes adjacent to BBS routes were related to bird population trends detected in BBS data. Within all 3 time periods examined (1970s, 1980s, and 1990s), the amount of mature forest adjacent to BBS routes was significantly lower than in surrounding 1° blocks of latitude and longitude. This could be problematic for studies that use roadside data to compare the relative abundance of species. On average, mature forest declined at a rate of −1.5% per year over the 28-year study period. We detected no significant difference in the rate of change between degree blocks and BBS routes over this time span. However, in the 1970s and 1980s, mature forest declined more rapidly in degree blocks (−2.7%/yr) than adjacent to BBS routes (−0.5/yr). We also found that the BBS trend for a mature forest-associated species, blackburnian warbler (*Dendroica fusca*), was correlated with the trend in mature forest along BBS routes. This, combined with slower rates of mature forest change along routes in the 1970s and 1980s, suggests that BBS data may have underestimated population declines during this period. It is important that research be conducted to test for potential biases in roadside surveys caused by uneven rates of landscape change, particularly in regions characterized by rapid habitat alteration. (JOURNAL OF WILDLIFE MANAGEMENT 71(7):2266–2273; 2007)

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KEY WORDS Acadian forest, bird population trends, blackburnian warbler, Breeding Bird Survey, habitat loss, landscape change, mature forest, New Brunswick, roadside wildlife surveys.

Recent concern about the rapid rate of biodiversity decline has highlighted the need for reliable large-scale, long-term ecological data (Butchart et al. 2004, Balmford and Bond 2005). To address this need efficiently, roadside surveys have been established for a variety of animal taxa including birds (McLeod and Andersen 1998, Conway and Simon 2003), amphibians (Royle and Link 2005, Weir and Mossman 2005), and mammals (Duckworth 1998, Drake et al. 2005).

The Breeding Bird Survey (BBS) is one of the most spatially extensive and long-term wildlife surveys in the world. Since the mid-1960s, data have been gathered by volunteers at over 4,000 39.4-km-long roadside survey routes (Robbins et al. 1986). These data have commonly been used to assess bird population trends (Keitt and Stanley 1998, Pardieck and Sauer 1999, Blackwell and Dolbeer 2001), species occurrence (O'Connor et al. 1996, Roseberry and Sudkamp 1998, Peterjohn 2001), and species diversity (La Sorte and Boecklen 2005) and to examine the effects of landscape fragmentation on species persistence (Donovan and Flather 2002). Trend and abundance estimates from BBS data are used extensively in setting North American land bird conservation priorities (Dunn et al. 1999, Carter et al. 2000).

Most studies using roadside survey data either implicitly or explicitly assume that samples are representative of the amount of habitat and its rate of change within 1° blocks of latitude and longitude or other large-scale study regions (Dunn et al. 1999, Pardieck and Sauer 1999, Donovan and Flather 2002). However, studies examining the degree to which survey routes represent these larger scales are rare and have been limited to regions where agricultural practices rather than forest management dominate (Bart et al. 1995, Keller and Scallan 1999). Such regions are likely to be characterized by more temporally stable land-use patterns in comparison to forest-dominated regions that often change rapidly as a result of timber harvest and forest succession (Betts et al. 2003).

The primary objective of this study was to test whether areas sampled by the BBS represent the amount of mature forest and the rate of change in this cover type at a landscape scale in New Brunswick, Canada. We also sought to determine whether land cover change adjacent to BBS routes influences bird population trends detected in BBS data; specifically, we predicted that mature forest decline along BBS routes would affect BBS population trend estimates for a mature forest indicator species, blackburnian warbler (*Dendroica fusca*; New Brunswick Department of Natural Resources 2000). If 1) land cover change along BBS routes is not representative of larger scales and 2) land cover change along BBS routes influences BBS population trends, these bird population trends will be biased. In such cases,

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trends in bird abundance evident along roadsides will not represent actual population trends occurring at larger scales.

STUDY AREA

New Brunswick (69.05°W–64.48°E, 48.02°N–44.60°S) was within the Acadian Forest Region (Rowe 1972). The province was characterized by 89% forest cover, a maritime climate, and mostly rolling topography (elevation 0–820 m). Forest cover was primarily tolerant hardwood (beech [*Fagus grandifolia*], sugar maple [*Acer saccharum*], and yellow birch [*Betula alleghaniensis*]), intolerant hardwood (white birch [*Betula papyrifera*], bigtooth aspen [*Populus grandidentata*], trembling aspen [*Populus tremuloides*], and red maple [*Acer rubrum*]), and mixed-wood communities (either tolerant hardwoods or intolerant hardwoods combined with red spruce [*Picea rubens*] and balsam fir [*Abies balsamea*]). However, pure softwood communities (red spruce, balsam fir, white spruce [*Picea glauca*], or black spruce [*Picea mariana*]) existed in low-lying areas and along the Bay of Fundy coast. Pure pine stands (white pine [*Pinus strobus*] or jack pine [*Pinus banksiana*]) were less common but existed primarily in post-burn areas of the province.

METHODS

According to BBS protocol, each BBS route should represent one surrounding degree block of latitude and longitude: 8,758 km^2 (Price et al. 1995, Lawler and O'Connor 2004). For this reason, we selected the $1° \times 1°$ blocks as the unit for comparison with roadside areas. We considered the area sampled by the BBS route to be the area within 150 m on either side of roads. The 150-m distance reflects the maximum extent within which most birds can be detected in unlimited-distance point counts (Scott et al. 1981, Ralph et al. 1995).

We selected mature forest for analysis because previous work indicates that it is most likely to exhibit rapid change; the amount of mature forest in this region is being harvested at a rate greater than it is being replaced (Betts et al. 2003). This is a conservation concern because a number of species appear to be associated with this successional stage (Higdon et al. 2005). Historically this forest type has dominated the landscape and is thus likely to be of particular ecological importance; prior to European settlement, most forest (>80%) in northeastern North America existed in a mature condition (Lorimer 1977, Mosseler et al. 2003).

We selected blackburnian warbler as a focal species a priori because it is known to be strongly associated with mature forest (Morse 2004, Young et al. 2005). Though the species is most prevalent in mixed coniferous deciduous forest, unlike other mature forest–associated species, it also occurs in mature forest that has a high proportion of either deciduous or coniferous trees (Young et al. 2005).

We examined the rate of change in mature forest along BBS routes and in degree blocks over the period from 1974 to 2001 using air photo data available in the New Brunswick forest inventory (New Brunswick Department of Natural Resources 1989). Though this method of forest inventory is prone to error (Franklin et al. 2000), it is sufficient for characterizing coarsely defined forest types (Dussault et al. 2001) and was used in predicting the distribution of many species of birds in the region with equivalent success to detailed vegetation field data (Betts et al. 2006). Further, in New Brunswick >80% of the air photo data are representative of forest cover data as verified in on-the-ground sampling (S. Makepeace, New Brunswick Department of Natural Resources, personal communication).

The New Brunswick forest inventory is conducted approximately every 10 years. Geographic Information System (GIS) data were available for public and small private land for the 1980s (photo dates: 1981–1985) and the 1990s (photo dates: 1993–2001; scale 1:12,500; time spans of air photos reflect the amount of time taken to photograph the entire province). As forest practices on the remaining land base (large private industrial) are required by law to reflect forest management on public land (Government of New Brunswick 1982), we do not expect that unavailability of data for these areas resulted in bias. We used data slightly beyond the 1990s (1993–2001) to maximize the spatial extent of air photo data in the most recent time period and to make the spatial extent of analysis the same as previous decades.

Geographic Information System data were not available for the 1970s so we relied on a sample of hard-copy air photo–derived forest inventory maps (photo dates: 1974–1976; scale 1:50,000) for the same study area used to compile 1980s and 1990s land cover data. We sampled maps from the 1970s using a stratified random design. First, to ensure that sample maps covered the entire spatial extent of degree blocks, we stratified each degree block into 8 subblocks. We then randomly selected one map from 9 maps that existed in each subblock (Fig. 1). The number of maps sampled was approximately proportional to the total terrestrial area of each degree block (range: 1–8). This resulted in a sampling intensity of 11% of the total study area. We placed acetate overlays with a 150-m grid over photo samples to tabulate mature forest area along BBS routes (following Keller and Scallan 1999). We used a coarser resolution grid (300 m) in degree blocks to maximize the spatial extent sampled. Using GIS data for New Brunswick from the 1990s we tested whether differences in sampling resolution resulted in different estimates of mature forest and found no substantial differences (<0.53%).

For all 3 time periods, either GIS (1980s, 1990s) or hard copy air photo data (1970s) were available for 65% of New Brunswick. We ensured that the areas sampled in all 3 time periods were identical by using the same subsampling approach in our tabulation of 1980s and 1990s GIS air photo data that were used with the 1970s hard-copy air photo data (Fig. 1). We tested the efficacy of this subsampling by comparing proportions of mature forest from subsamples with the proportion of mature forest in the entire 65% of the province for which data were available. We conducted subsampling at sufficient intensity to reflect the actual amount of mature forest existing at the provincial scale in both the 1980s (mature forest sample $\bar{x} = 60.5 \pm 2.0\%$, mature forest New Brunswick $\bar{x} = 63.5 \pm 1.7\%$, $t = 1.2$, $P = 0.26$, difference in means = 3.1 [95% CI = −8.6 to 2.4]) and the 1990s (mature forest sample $\bar{x} = 52.8 \pm 2.4\%$, mature forest New Brunswick $\bar{x} = 49.2 \pm 4.5\%$, $t = 0.7$, $P = 0.49$, difference in means = 3.6 [95% CI = −7.3 to 14.6]). Of the 34 BBS routes in New Brunswick, 22 fell within the area of New Brunswick for which data were available in all time periods. We used data for only these 22 routes in analysis.

For all time periods, we calculated the proportion of mature forest within 150 m of 22 BBS routes and for degree block samples. We excluded ocean from the calculation of proportions. We used predefined age class categories to identify mature forest for the 1980s and 1990s (New Brunswick forest inventory: immature, mature, and overmature; New Brunswick Department of Natural Resources 1989). The lower age limit of these categories varied depending on the dominant tree species contained within stands (New Brunswick Department of Natural Resources 1989; Appendix). Predefined age class categories were not available for the 1970s so we used tree size and timber volume classes as proxies in the definition of mature forest for the 1970s. We considered mature forest to be stands with >35 m^3 merchantable timber/ha and with timber volume constituted primarily by trees >16 cm diameter at breast height (New Brunswick Forest Inventory Classes I and II). These criteria most closely reflect stand structure characteristics of immature, mature, and overmature classes in the 1980s and 1990s inventories (New Brunswick Department of Natural Resources 1989). Our criteria for defining mature forest necessarily differed between the 1970s versus the 1980s and 1990s, which may have resulted in an under- or overestimation of mature forest change across years; thus our estimates of mature forest decline for the first decade of the study should be interpreted with caution. However, because we used the same method to define the amount of mature forest along BBS routes and in degree blocks within each time period (1970s, 1980s, and 1990s), our test for differences between BBS routes and degree blocks is not biased. Differences between BBS routes and degree blocks within each time period, and differing rates of change among time periods, are thus due to actual differences in forest age rather than discrepancies in forest characterization.

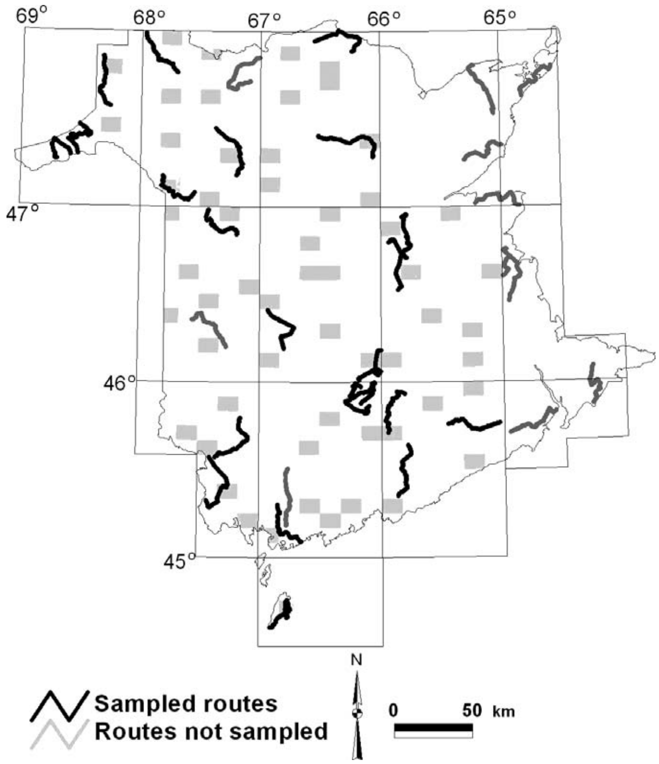

Figure 1. Breeding Bird Survey routes in relation to blocks of 1° latitude and longitude (degree blocks) in New Brunswick, Canada. Routes marked in grey were not sampled due to unavailability of land cover data. Light grey rectangles are subsamples used to characterize degree blocks in all 3 time periods.

Statistics

We calculated the percent change in mature forest and agricultural land using methods that parallel the approach generally used to describe trends in avian populations from the BBS. We calculated change (c) in habitat as $c = r^{1/t}$, where r is the ratio of the proportion of present cover to past cover and t is length of the time span observed (after Bart et al. 1995). We calculated percent change per year as $100(c - 1)$. When more than one route occurred in a degree block (7 of 10 cases), we averaged mature forest values for all routes occurring within each block ($n = 10$ for routes and degree blocks). We calculated annual rates of change using the year for which the most air photos were collected within each time period (1970s: 1975; 1980s: 1983; 1990s: 1996).

We tested for differences in the amount of mature forest adjacent to BBS routes versus degree blocks within 3 time periods: 1970s, 1980s, and 1990s. We also tested for differences in rates of mature forest change for 1970s–1980s, 1980s–1990s, and 1970s–1990s. We used 2 separate methods to test whether the amount of mature forest along BBS routes, and its rate of change over time, represent what occurred in degree blocks. The first method tests whether routes are representative of their associated degree blocks (degree block scale). Results of this method are relevant to researchers who use degree blocks or individual routes within a region as sample units (e.g., Boulinier et al. 2001, Donovan and Flather 2002, Vance et al. 2003). In this analysis, we used Generalized Estimating Equations (GEE; procedure GENMOD of SAS using the statement REPEATED; SAS Institute Inc. 1999) to account for the paired design (routes within degree blocks; Liang and Zeger 1986). In GEEs, we specified an exchangeable working correlation structure with a normal error distribution and identity link function, with route and block location as the clustering variable. This analysis considers each degree block as statistically independent, but assumes that routes within degree blocks are correlated.

The second method we used tests whether, on average, BBS samples tend to represent the amount of mature forest

Table 1. Statistical comparison of the proportion of mature forest along Breeding Bird Survey routes (BBS) in New Brunswick, Canada, and surrounding degree blocks (DB) from 1974 to 2001.

Period	BBS (%)	DB (%)	$\bar{x}$ difference (%)	Degree block scale[a]			Regional scale[b]		
				χ^2	CI	P	t	CI	P
1970s	49.0	71.5	22.5	40.9	15.6–29.3	<0.001	6.3	15.5–29.5	<0.001
1980s	46.0	60.5	13.5	21.7	7.8–19.1	<0.001	4.6	7.7–19.3	<0.001
1990s	39.1	52.8	13.7	19.5	7.6–19.8	<0.001	4.4	7.7–19.8	<0.001

[a] Using Generalized Estimating Equations.
[b] Using Generalized Linear Models.

and the rate of change within the region (i.e., at the scale of the province of New Brunswick as a whole [provincial scale]). In this case, degree blocks were still the sample unit; however, we eliminated the paired design. Results of this method are relevant to studies that use BBS data to determine regional trends (e.g., Holmes and Sherry 1988, Link and Sauer 1994). We used generalized linear models (GLMs) to test for differences in rates of change within each period as a function of location (routes vs. degree blocks). In GLMs, we used a normal error distribution and identity link function.

The large spatial extent of our sample units (degree blocks) limited our sample size resulting in decreased power to detect differences. Thus, in tests for differences in rates of mature forest change over multiple time periods we did not apply Bonferroni corrections to our alpha level ($\alpha = 0.05$). We considered the costs of Type II error (accepting H_0 that BBS routes are representative of broader landscapes if in fact they are not) to be greater than those of Type I error (Nakagawa 2004). In initial analysis, data on the proportion of mature forest along routes and in degree blocks were arcsine square-root transformed (Zar 1999). However, we present results of analyses using untransformed data because these did not differ substantively and ease interpretation.

As the BBS is a land bird survey, degree blocks with high proportions of ocean are down-weighted in trend calculations (E. Dunn, Environment Canada, personal communication). We reanalyzed data excluding degree blocks with >20% ocean and results did not differ qualitatively.

We tested for the relationship between the change in mature forest adjacent to BBS routes and route-level trends in blackburnian warbler abundance from 1974 to 2001 using GLM with a normal distribution and identity link function. We tested for regression outliers using plots of Cook's distance. We analyzed data both with and without outliers. We estimated route-level trends from raw abundance data using GLMs with a Poisson distribution and a log link function. We controlled for observer variation by including an observer term in all models as a covariate (after Sauer et al. 2005). We considered only routes that were sampled over the full range of the 1974–2001 period, had ≥2 years of data in the first and last decades of analysis (1970s, 1990s), and included >10 years of data. To increase the number of routes examined, we included bird abundance data from 3 years prior to, and after the available air photo dates (i.e., spanning the period 1971–2004). Province-wide trends were provided by the United States Geological Survey Patuxent Wildlife Research Center (http://www.mbr-pwrc.usgs.gov/bbs/bbs.html; Sauer et al. 2005). All means are reported ± standard error.

RESULTS

Within all 3 time periods examined (1970s, 1980s, and 1990s), the amount of mature forest along BBS routes was significantly lower than in surrounding degree blocks (Table 1). In the first time period (1970s), mature forest was 1.5 times more common in degree blocks than along BBS routes. However, this difference was reduced in the most recent decades examined (1980s and 1990s) where mature forest was 1.3 times more prevalent in degree blocks than along BBS routes (Table 1).

We found that mature forest declined 4.8 times faster in degree blocks than along BBS routes between the 1970s and 1980s (–2.7% vs. –0.5%; Table 2; Fig. 2). However, we did not detect a difference between the rate of mature forest change either over the full period examined (1974–2001) or in the most recent decade (1985–2001; Table 2; Fig. 2). Confidence intervals around estimates of mean differences in rates of change in both the 1985–2001 and 1974–2001 periods indicate that rates of change in degree blocks and

Table 2. Mean annual rate of change in mature forest from 1974 to 2001 along Breeding Bird Survey Routes (BBS) and surrounding degree blocks (DB) in New Brunswick, Canada.

Period	BBS (%)	BBS SE (%)	DB (%)	DB SE (%)	$\bar{x}$ difference (%)	Degree block scale[a]			Regional scale[b]		
						χ^2	CI	P	t	CI	P
1974–1985	−0.5	0.8	−2.7	0.3	−1.9	5.3	−3.5 to −0.2	0.021	2.1	−3.6 to −0.2	0.045
1985–2001	−1.4	0.3	−1.1	0.3	0.7	1.0	−0.3 to 1.1	0.691	0.9	−0.4 to 1.1	0.722
1974–2001	−1.1	0.3	−1.5	0.1	−0.4	1.7	−1.0 to 0.2	0.187	1.3	−1.0 to 0.2	0.219

[a] Using Generalized Estimating Equations.
[b] Using Generalized Linear Models.

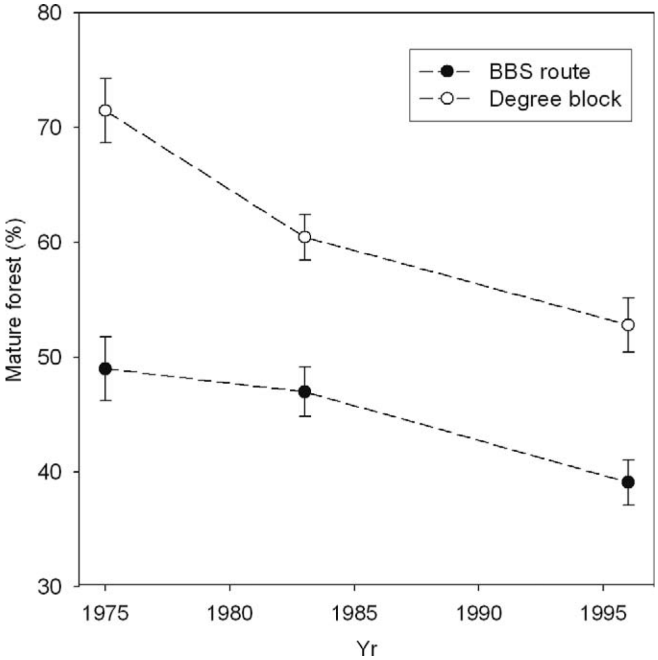

Figure 2. Amount of mature forest (%) within 150 m of Breeding Bird Survey (BBS) routes and within degree blocks from 1974 to 2001 in New Brunswick, Canada.

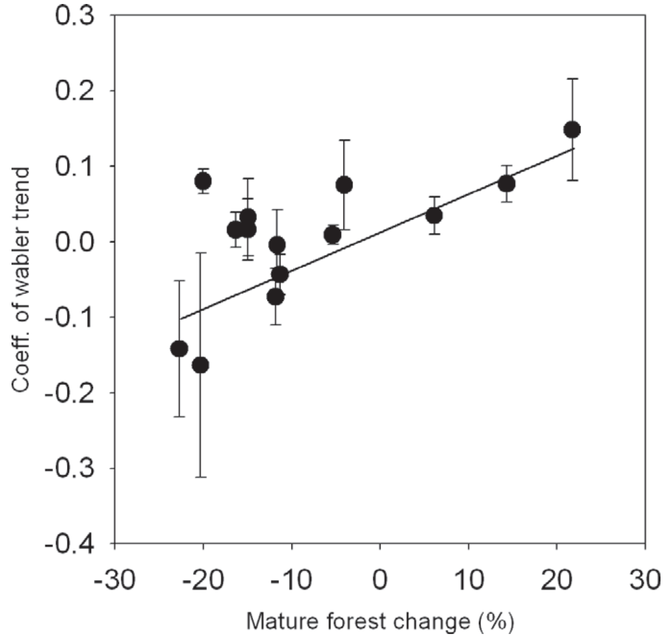

Figure 3. Relationship between change in mature forest within 150 m of Breeding Bird Survey (BBS) routes from 1974 to 2001 and the estimated trend for blackburnian warbler for the same time period in New Brunswick, Canada. Error bars represent standard errors of coefficients from route-level trend models.

along BBS routes are not likely to differ >1.1% per year during these time spans (Table 2).

As predicted, mature forest decline along BBS routes appeared to affect BBS population trend estimates for a bird species strongly associated with mature forest. The trends in mature forest along routes were positively related to BBS trend estimates for blackburnian warbler ($r^2 = 0.45$, $F = 9.7$, $P = 0.01$, $n = 14$; Fig. 3). This relationship remained when we removed outliers ($r^2 = 0.53$, $F = 10.3$, $P = 0.01$, $n = 11$). Thus, land cover change adjacent to BBS routes seemed to influence population trends detected in BBS data.

DISCUSSION

We found that the tendency of BBS routes to represent mature forest change varied depending on the time period examined. We did not detect a difference in the rate of change over the entire 1974–2001 period or in the most recent time span (1980s–1990s). The rate of change adjacent to BBS routes in these periods was representative of change in degree blocks. However, from the 1970s–1980s, the rate of mature forest decline was more rapid in degree blocks in both provincial and regional scale analysis.

We hypothesize that this discrepancy could be the result of 2 factors. First, the rate of mature forest harvest may have been reduced in roadside areas during this period. In New Brunswick, areas managed primarily for timber (industrial forest land) tend to be more prevalent away from paved roads. Further, areas immediately adjacent to roads often remain uncut to limit the aesthetic impact of clearcut harvesting (Lansky 1992). Second, similar to other regions of northeastern North America, there has been a trend of agricultural land abandonment followed by forest succession over the past century (Zelazny et al. 1997). Agricultural lands recolonized by forest during the 1920s–1930s would have entered mature age classes during the 1970s. Because agricultural land is more common adjacent to roads, the emergence of new forest may have compensated for the amount harvested, resulting in only small changes to the total amount of mature forest.

Poor representation of change for one of the 2 decades examined may have implications for avian population estimates. We found that BBS trends for blackburnian warbler are related to trends in mature forest along routes. Routes exhibiting mature forest decline were the most likely to exhibit blackburnian warbler decline, as one would expect given the strong association of this species with this forest type (Young et al. 2005). However, this has important implications for BBS trend estimates. Throughout the period of most rapid decline in mature forest across New Brunswick (1970s–1980s), mature forest adjacent to BBS routes changed very little (–0.5%/yr). If blackburnian warbler population size is linked to the amount of mature forest, as our results and others suggest is the case (Young et al. 2005), less rapid changes in roadside areas would have masked a population decline occurring at the provincial scale during this period. Indeed, analysis of BBS data revealed no significant change in abundance of this species in New Brunswick from 1974 to 1985 (+3.2%/yr, $P = 0.56$, $n = 16$; Sauer et al. 2005). However, from 1985 to 2001 when BBS routes represented mature forest change in degree blocks, the species exhibited a significant decline (–5.1%/yr, $P = 0.005$, $n = 23$; Sauer et al. 2005).

Not surprisingly, we found that the amount of mature forest adjacent to BBS routes is not representative of degree blocks in New Brunswick in any of the time periods observed. This is likely because areas along established roads have historically been more accessible for settlement, agriculture, and timber harvesting, and they tended to be exploited first. Several authors have recognized that abundance data obtained from roadside areas may not be representative of landscape cover beyond the narrow band surveyed (Peterjohn and Sauer 1994, Donovan and Flather 2002). These results were apparent in previous studies of cover type sample bias in BBS routes (Keller and Scallan 1999) and along roads in general (Bart et al. 1995). This is problematic if roadside data are used to estimate and then compare species abundances (as opposed to trends) at landscape, regional, or continental scales (e.g., O'Connor et al. 1996, Husak and Linder 2004, La Sorte and Boecklen 2005). Differences in the proportion of birds counted due to roadside variability in habitat could be misinterpreted as geographic differences in population size (Bart et al. 1995).

We found a consistent decline in mature forest in New Brunswick. Rates of forest change in landscapes in each period examined tended to be more rapid (range: −2.7%/yr to −1.0%/yr) than those reported in agricultural landscapes (Bart et al. 1995: +0.64%/yr in OH; Keller and Scallan 1999: <+0.10%/yr in OH, <−0.04%/yr in MD). This supports our expectation that forest landscapes are sometimes more dynamic than agricultural landscapes. Though rates of change from 1970s–1990s should be interpreted with caution due to differences in forest characterization in the 1970s, the decline in mature forest that we report for 1980s–1990s is likely to be accurate (−1.1%/yr). Previous studies have also reported extensive decline in mature forest in New Brunswick since European settlement (MacDougall 2001, Betts and Loo 2002) and in recent decades (Betts et al. 2003, Etheridge et al. 2005). This reflects a decline in mature forest in other parts of North America (e.g., Schulte et al. 2005). The rapid rate of change we report is of concern given the historical prevalence of mature forest in northeastern North America (Mosseler et al. 2003). For comparison, mangrove forest, considered one of the most threatened ecosystems globally (Barbier 2006), is characterized by a 1.5% per year decline (Valiela et al. 2001). Continued habitat loss and fragmentation of mature forest in New Brunswick could threaten the persistence of a number of mature forest–associated species (Imbeau et al. 2001).

Sources of Error

Due to variation in data availability and type between the first and last 2 time periods and the inherent errors in air photograph interpretation, some error undoubtedly exists in our estimates of the amount of mature forest and the rates of mature forest decline. However, we think it improbable that these potential errors translate into bias in the comparison of BBS routes and degree blocks within a time period or the relative rates of change among time periods. For the former to have occurred, air photograph interpreters would need to have adopted different methods for defining forest types in 150-m roadside zones versus the rest of the province. Alternatively, photo interpretation error rates must have differed between roadsides and degree blocks. Both of these occurrences are highly unlikely. More importantly, our estimates of mature forest decline from 1970s to 1990s and from 1970s to 1990s may be either under- or overestimated because our definition of mature forest in the 1970s necessarily differed. However, differences in mature forest definition would not have influenced the discrepancies in the rates of change between BBS routes and degree blocks. Increasing or decreasing the amount of mature forest that existed in the 1970s would change the slope of mature forest decline, but the difference in slope between routes and degree blocks across time periods would remain the same (Fig. 2).

MANAGEMENT IMPLICATIONS

Both trend (Askins 1993, Dunn et al. 1999, Butchart et al. 2004) and abundance estimates (Carter et al. 2000) are frequently used in setting conservation priorities. Precision and consistency in addition to the magnitude of trends are also considered important (Greenwood et al. 1994, Dunn 2002). If biases occur in BBS data as a result of uneven landscape change, even over portions of the period being considered (as we have observed), conservation efforts could potentially be misdirected. For these reasons, we think it is important to undertake similar tests in other regions. Priority should be given to regions that are likely to be experiencing the greatest rates of change. Further, cover types that are predicted to be declining at the greatest rate (e.g., mature forest, grassland) should be prioritized for study. Our study benefited from a forest inventory that spans nearly 3 decades. Though such long-term spatially explicit data have been rare or difficult to obtain for large areas in the past, the prevalence of GIS and remotely sensed data available at reasonably high resolutions (Pettorelli et al. 2005) should facilitate such analysis in the future.

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Appendix. Numerical age of maturity for New Brunswick, Canada, tree species, defined here as including immature, mature, and overmature development stages from the New Brunswick Forest Inventory (New Brunswick Department of Natural Resources 1989).

Species	Age (yr)
Balsam fir (*Abies balsamea*)	>35
Red spruce (*Picea rubens*)	>45
Black spruce (*Picea mariana*)	>45
White spruce (*Picea glauca*)	>40
White pine (*Pinus strobus*)	>50
Jack pine (*Pinus banksiana*)	>40
Red pine (*Pinus resinosa*)	>40
Eastern cedar (*Thuja occidentalis*)	>45
Eastern hemlock (*Tsuga canadensis*)	>50
Larch (*Larix laricina*)	>45
Tolerant hardwoods (primarily sugar maple [*Acer saccharum*], yellow birch [*Betula alleghaniensis*], beech [*Fagus grandifolia*])	>50
Intolerant hardwoods (primarily white birch [*Betula papyrifera*], aspen [*Populus* spp.], red maple [*Acer rubrum*])	>35