POPULATION TRENDS FROM THE AMERICAN WOODCOCK SINGING-GROUND SURVEY, 1970–88

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Abstract: Population trend analysis of American woodcock (*Scolopax minor*) using data from a singing-ground survey indicates population declines throughout the breeding range of the species between 1970 and 1988. In the eastern United States and Canada, this decline has been quite consistent throughout the period, but in the central portion of the continent the population increased during the 1970's and declined during the early 1980's. Observers differ in their ability to hear woodcock, and we document observer differences in the singing-ground survey data and incorporate them into our analyses. Habitat changes have been suggested as the most likely cause of declines in woodcock populations.

J. WILDL. MANAGE. 55(2):300–312

The American woodcock is distributed throughout eastern North America and is a popular game bird. Current estimates indicate that 3.5 million person-days were spent harvesting woodcock in the United States and Canada in 1985 (U.S. Dep. Inter. 1988). Woodcock are difficult to survey because they are cryptic, crepuscular, and occupy shrubby second-growth habitats (Sheldon 1971). Because of difficulties associated with capturing sufficient numbers of woodcock, year-specific survival and harvest rates are not readily estimated with banding analyses. Instead, the U.S. Fish and Wildlife Service (USFWS) and the Canadian Wildlife Service manage woodcock populations with annual information from 2 surveys, a harvest survey and a singing-ground survey (M. C. Bateman, Preliminary Report to Canadian Woodcock Singing Ground Cooperators, Can. Wildl. Serv., Sackville, N.B., 1988; J. B. Bortner, American Woodcock Harvest and Breeding Population Status, USFWS, Laurel, Md., 1988). In recent years, changes have been suggested in the design and analysis of both of these surveys (Owen 1977, Tautin et al. 1983). In this paper we analyze the singing-ground survey using route-regression methods (Geissler and Sauer 1990).

The Singing-Ground Survey

Woodcock are surveyed in eastern and central United States and Canada with a roadside survey procedure (Mendall and Aldous 1943, Owen 1977). In the survey, permanent roadside routes are set up on lightly traveled secondary roads, and surveys are run yearly on these routes. Changes in counts along these routes are then used to estimate population changes in woodcock. Initially, woodcock survey routes were located in areas of high woodcock abundance, but in the late 1960's routes were located with randomly chosen starting points to ensure that they were representative of habitats within states (Clark 1970). The present singing-ground survey was initiated in certain states starting in 1968 and has been run in all regions included in the survey since 1971. (See Table 1 for a list of states and provinces contained in the survey area.)

To conduct a survey route, observers drive a predetermined 6-km segment of secondary roads. Routes are surveyed 1 time per year, shortly after sunset during the peak of spring courtship activity of woodcock. Observers stop at 10 preselected locations on a route and record the number of woodcock heard singing during a 2-minute observation period. The total number of woodcock heard at the 10 stops is used as an index of woodcock population size.

Criticisms of the Singing-Ground Survey

To be a valid index to woodcock abundance, counts of singing males must be related to actual population sizes of woodcock in some consistent manner (Bart and Schoultz 1984). For woodcock, the validity of the singing male index has been criticized for several reasons (Dwyer et al. 1988). Nonsinging males exist in woodcock populations (Sheldon 1971), and variation in the proportions of these nonsurveyed birds could invalidate the index. Dwyer et al. (1988) found that young (second yr) adults tended to remain as subdominants at singing grounds rather than move to new forest openings when they became available, resulting in a constant number of singing males even though the actual male population was increasing. They found no correlation between singing male woodcock and actual population densities over 5 years at a study site in Maine (Dwyer et al. 1988). However, 1 other study did find significant correlations between indirect estimates of population size and singing male counts (Whitcomb and Bourgeois 1974).

The ability to perceive singing woodcock varies greatly among observers (Duke 1964, Clark 1970, but also see Tautin 1982). In past analyses of singing-ground survey data, observer differences have been acknowledged to influence count data on routes, and the base year method (Geissler and Noon 1981) was used to estimate annual indices of population size. In the base year method, an average population index is found for some base year, and indices in later (or earlier) years are found by multiplying (or dividing) base year indices by the change calculated from comparable (e.g., run by the same observer) route data. Unfortunately, the base year method can provide biased estimates of trends when applied to a series of years because errors in estimates of change are multiplied and they accumulate. Also, variances of trend estimates from base year indices tend to be too small, because variances are estimated among years rather than among routes, and the indices contain autocorrelation (Geissler and Noon 1981).

To minimize observer effort on survey routes that contain few woodcock, the singing-ground survey coordinators adopted the convention that routes on which no birds were heard for 2 consecutive years go into a constant zero status. These routes are not run for the next 5 years, and zero counts are assumed. The sixth year, the route is resurveyed, and if no birds are heard it stays in constant zero status for another 5 years. If birds are heard the sixth year, the route is reactivated. Although the constant zero data have been included in analysis of the singing-ground survey data, the assumption that constant zero counts are equal to zero counts may be invalid (S. L. Stokes, Patuxent Wildl. Res. Cent., unpubl. memo).

The purpose of our paper is to present an analysis of the singing-ground survey with the route-regression method developed by Geissler and Noon (1981) and Geissler and Sauer (1990). This method is currently used to analyze data from the North American breeding bird survey (Robbins et al. 1986) and the USFWS mourning dove (*Zenaida macroura*) call-count survey (D. D. Dolton, Mourning Dove Breeding Population Status, USFWS, Laurel, Md., 1988).

In the singing-ground survey, several variants of the route-regression method are possible. Collins (1987) used a modified route-regression method that did not incorporate observer differences to analyze singing-ground survey data. We incorporate observer differences in our analysis, and we assess the effects of both changes in observers and constant zero routes on the population trend analysis.

We thank R. J. Blohm, T. J. Dwyer, J. D. Nichols, and W. Link for reviewing the manuscript. H. C. Bourne and D. S. Chu assisted with the statistical analysis and preparation of figures, and S. Droege and D. Bystrak provided information and comments on the breeding bird survey.

METHODS

Density Map

Although regional differences in detection probabilities may exist, counts from the singing-ground survey provide information on relative population size throughout most of the breeding range of the American woodcock. We calculated average counts for each route from 1970 to 1988 and used these data as input into program SURFER (Golden Software Inc., Golden, Colo.) to produce a contour map of estimated relative density for woodcock.

The Route-Regression Method

We used the route-regression method (Geissler and Noon 1981, Geissler and Sauer 1990) to produce unbiased estimates of trend and its variance (Geissler and Sauer 1990) for singing-ground survey data collected between 1970 and 1988. In this method, population trends are estimated for each route (indexed by i) with linear regression of the natural logarithm of counts ($C_{i,j}$) by year (indexed by j),

$$\ln(C_{i,j} + 0.5) = b'_{1,i} + b'_{2,i}j + \sum_{k=3}^{l+2} b'_{k,i}O_{k-2,i}. \quad (1)$$

In the regression, observer data are incorporated as dummy variables; there are $l = (n$ of observers $- 1)$ of them for each route, denoted as $O_{k,i}$ in equation (1) (Neter and Wasserman 1974). These dummy variables yield a common trend estimate among all observers, and they allow differences in the observers' abilities to hear wood-

Table 1. Population trends (in % change/yr) and sample sizes (n) of routes for states and provinces, eastern and central management units, United States, Canada, and entire survey area, 1970–88. Base year results are presented from the same period for comparison.

Region	Route-regression		Base yr trend
	Trend	n	
Eastern unit			
Conn.	−5.48	9	−3.08**[1]
Me.	−2.12	62	−2.79**
Md.	−7.27**	24	−4.91**
Mass.	−6.03	19	−2.59
N.B.	−3.04**	61	−1.16
N.H.	0.19	18	−5.11**
N.J.	−7.69*	15	−4.74**
N.Y.	−0.66	100	1.41
N.S.	−2.38	50	−2.53**
Pa.	−6.74**	54	−2.41**
Prince Edward Isl.	2.22	12	−2.79*
Que.	3.84*	57	1.60
R.I.	−10.72	2	−7.40**
Vt.	−3.30**	22	−0.59
Va.	−6.82**	54	−4.06*
W.Va.	−1.50	45	−2.03*
Unit	−1.39**	604	−1.69**
Central unit			
Ill.	−6.83	34	−2.31**
Ind.	−3.27	40	0.47
Mich.	−1.10	135	0.49
Minn.	0.84	102	1.80*
Oh.	−3.98	67	−2.51**
Ont.	−0.90	125	0.50
Wis.	−1.64	103	1.37*
Unit	−1.16*	606	0.73
United States	−1.71**	905	−0.47
Canada	−0.31	305	−0.12
Entire survey	−1.26**	1,210	−0.35

[1] Test of the null hypothesis that trend is equal to zero. * $P < 0.05$; ** $P < 0.01$.

cock. This eliminates bias in route (and therefore regional) population trends caused by changes in observers. The slope of this regression ($b'_{2,i}$) is then back-transformed (Bradu and Mundlac 1970) to provide an unbiased estimate of slope (b_i) in a multiplicative model of population change.

State and province estimates of trend ($\bar{b}$) are found as weighted averages of route slopes (b_i),

$$\bar{b} = \frac{\sum_{i=1}^{n} \frac{\bar{c}_i b_i}{v_i}}{\sum_{i=1}^{n} \frac{\bar{c}_i}{v_i}}, \qquad (2)$$

where v_i is the relative variance (Geissler and Sauer 1990) of route i, $\bar{c}_i$ is the average count on route i, and n routes occur in the state or province. Regional estimates are further weighted by land areas of the component state or provinces.

Variances are found by bootstrapping the regional trend estimates (Efron 1982). Z-tests are used to assess the significance of the test that regional trends are different from zero. Results are presented as percent change per year.

Woodcock are managed in eastern and central units, which were derived from analysis of band recovery data (Coon et al. 1977). We estimated population trends for each state and province included in the survey, and for the management units (Table 1). Finally, we produced estimates for the United States, Canada, and the entire survey area.

Annual Indices from Route-Regression.—In the singing-ground survey, annual indices of abundance cannot be estimated as yearly average counts because observer differences and inequities in route densities can introduce spurious patterns in the average counts (Geissler and Noon 1981). We estimated annual indices for states, provinces, and management units by estimating residual variation on each route after the regional trend had been removed. Regional trends were estimated, then the linear regressions were calculated for each route with the regional slope parameter fixed. From these regressions, we calculated expected values and residuals for each year. These route residuals were averaged by year, added to the regional predicted trend value, and back-transformed by exponentiation to form the yearly indices of abundance (Sauer and Geissler 1990).

Route-Regression, Constant Zero.—We included constant zero data in a route-regression analysis to assess the effects of their inclusion on the trends. Although these results provide no information on the effects of constant zero routes on the estimation procedure because we cannot determine if birds would have been heard during these constant zero years, we can still determine if adding the constant zero routes changes the results of the analysis. Constant zero data are not associated with an observer, therefore the estimates were computed without observer covariables. We assessed the consequences of adding constant zero data by calculating the difference between slopes on each route calculated with and without constant zero data. These differences were averaged by state and province. Because routes that have never registered a woodcock provide no information regarding population trends, these routes were not considered.

Observer Versus No Observer Route-Regression.—Because regional trends are found as weighted averages of route trends, including observer covariables on individual routes can affect regional trend estimates. To assess the importance of observer covariables in the singing-ground survey analysis, we used standard statistical methods for assessing the importance of adding variables into a regression (Neter and Wasserman 1974). In the absence of autocorrelation, the statistical significance of adding variables to a linear model can be assessed using an F-test to compare full (including observer covariables) versus reduced (no observer covariables) models. We examined a sample of singing-ground survey routes and determined that autocorrelation (as determined from significant results in Durbin-Watson tests) exists among counts collected over time on some of the routes. Hence, the actual statistical significance of the F-tests calculated from singing-ground survey data may differ from the estimated P-value. We used pooled error sums of squares for each route in the state or province to calculate F-tests as follows:

$$F = \frac{\dfrac{\sum_{i=1}^{M} (\text{MSE df}) - \sum_{i=1}^{M} (\text{MSE}' \text{df}')}{\sum_{i=1}^{M} \text{df} - \sum_{i=1}^{M} \text{df}'}}{\dfrac{\sum_{i=1}^{M} (\text{MSE}' \text{df}')}{\sum_{i=1}^{M} \text{df}'}}, \quad (3)$$

where M is the number of routes, MSE′ is mean-squared error for the regression on route i with observer covariables included, MSE is mean-squared error for the regression on route i without observer covariables, df′ is the degrees of freedom for route i with observer covariables, and df is the degrees of freedom for route i without observer covariables. The F-statistics provide a relative measure of the increase in fit associated with the addition of observer covariables.

Trends of Other Bird Species

Because woodcock populations might be changing in response to habitat changes, we examined the population trends of 14 species of eastern birds that use habitats similar to that of woodcock, using data from the North American breeding bird survey. The breeding bird survey is a roadside survey in which over 2,000 survey routes are censused each year in the United States and Canada. We estimated population trends of these species for the period between 1966 and 1987 for the United States east of the Mississippi River and corresponding parts of Canada (Robbins et al. 1986) with the route-regression method. In this analysis, we only used species with breeding distributions similar to that of woodcock, and we did not use "feeder species" that closely associate with human habitations.

RESULTS

Density Map

Breeding densities of woodcock tend to increase in the United States with latitude (Fig. 1). The southern region of the survey (Md., Va., W. Va., Ill., Del., N.J., and parts of Pa., Ind., and Oh.) has very low woodcock counts on routes. Woodcock are quite abundant in areas adjacent to the Great Lakes in both the United States and Canada, reaching their highest relative densities in parts of Ontario. There are also high relative densities of woodcock in northern New England and in the Maritime Provinces.

Population Trends

Our analysis, using route-regression with observer covariables, indicated regional declines in woodcock populations. Significant declines occurred in the United States and over the entire survey area, and Canada had a negative but not statistically significant trend (Table 1). Base year estimates are also presented for comparative purposes (Table 1).

Woodcock populations declined in abundance in the eastern United States and Canada (Table 1). Of the 16 states and provinces in the eastern unit (Del. was excluded due to insufficient coverage), 13 had declining populations, and 7 of these declines were statistically significant ($P < 0.05$). Only Quebec had increasing woodcock populations, and these results may not be representative of the province (see below). Woodcock also tended to decline in the central unit. Seven of the 8 states and provinces in the unit had declining populations, although no state or province had statistically significant declines.

Fig. 1. Estimated relative density of American woodcock throughout the range of the singing-ground survey, estimated from average counts over the period 1970–88 on singing-ground survey routes.

Annual Indices of Abundance

Annual indices of abundance indicate heterogeneity in patterns of population change among states and provinces in the eastern unit (Fig. 2), central unit (Fig. 3), and for the regions (Fig. 4); they reflect the south–north gradient in population density. Northern states and provinces in the central unit show a period of high populations in the mid- to late 1970's, followed by a decline in the early 1980's. This overall pattern also is apparent in the annual indices for the central unit (Fig. 4). The population trend estimate is defined as the population change in the midyear of the interval of interest; the midyear is 1978, hence the generally declining trends described here are an accurate reflection of changes in the population.

Population changes in states and provinces in the eastern unit also describe generally declining populations (Fig. 2). Populations in the east do not, however, show the population peak in the 1970's that occurred in the central unit. Populations in several states and provinces were low in the early 1980's, possibly reflecting a population low associated with an early spring storm in 1982 (Robbins et al. 1986). These patterns also occur in annual indices for the eastern unit (Fig. 4).

Indices for the United States, Canada, and the entire survey area reflect many of the regional changes discussed above (Fig. 4). Low index values in 1982 can be detected in all regions, and index values below the trend line for several years after 1982 indicate that the storm might have had a real effect on numbers of woodcock and that the low index values in 1982 might not have been completely due to a delayed breeding season.

Comparison with Base Year Analyses

Estimates of trends within states and provinces differed between route-regression and base year analyses, but were generally similar, and in no state or province did the different methods provide results that directly conflicted (e.g., changed from a statistically significant increase to a significant decline). In the eastern unit, our results are very similar to the earlier analyses, with an eastern unit trend of −1.69 from the base year results. However, in the central unit the addition of the observer covariable caused the unit trend estimate to indicate a significant decline in woodcock populations (-1.16, $P < 0.05$). The central unit estimates of trend were positive but not statistically different from zero for both the base year analysis and the route-

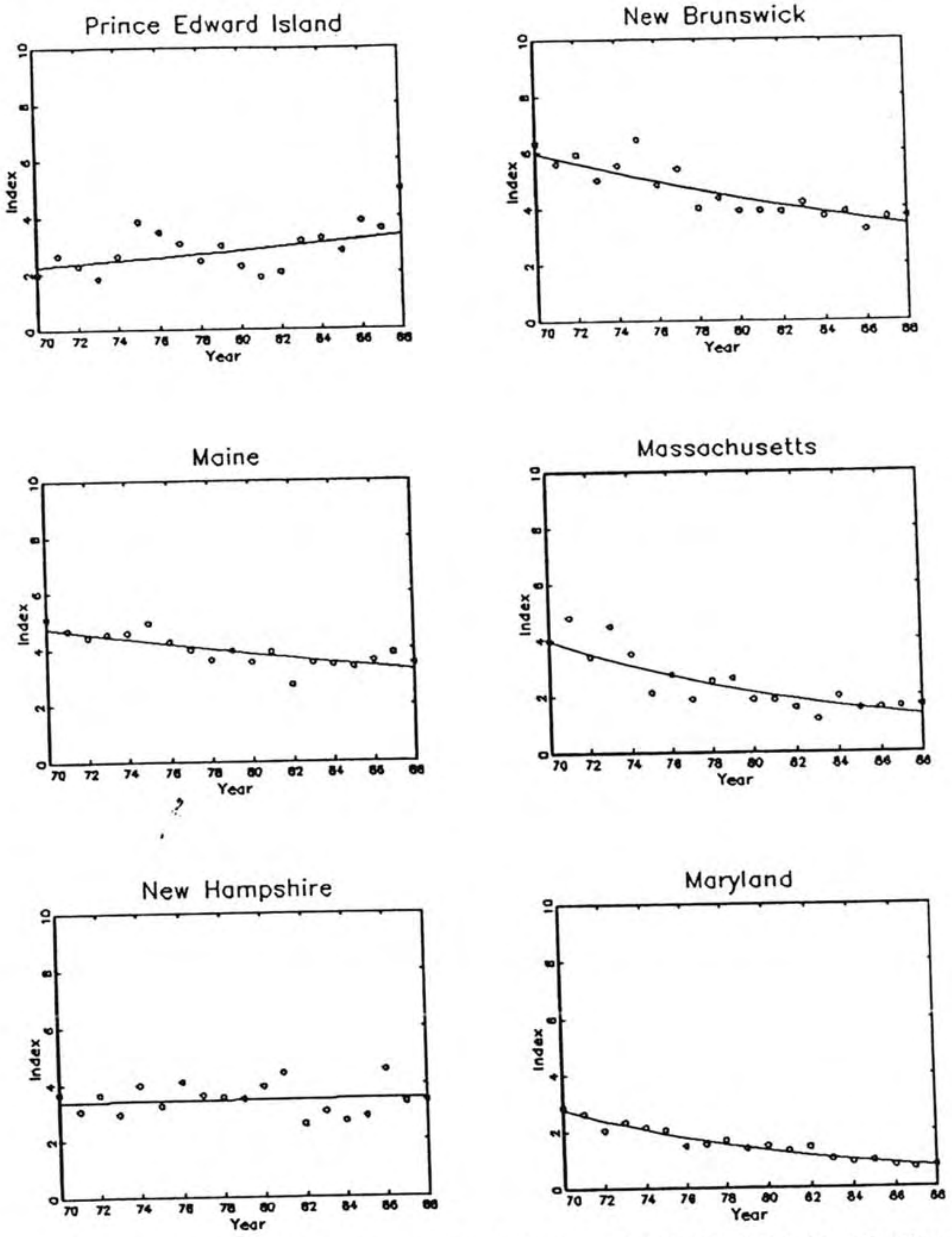
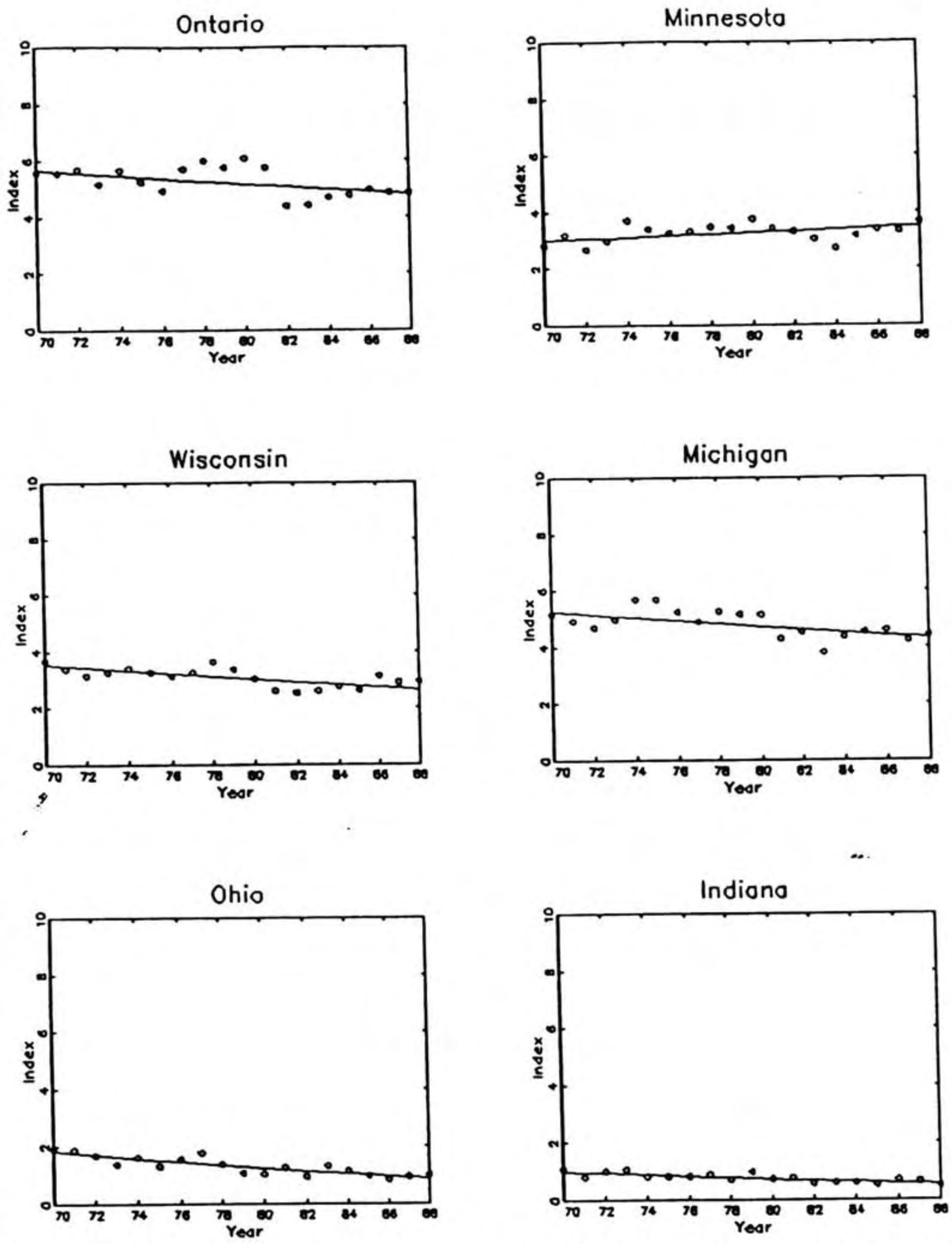


Fig. 2. Annual indices of abundance by year (○) and predicted population trends (solid line) for selected states and provinces in the eastern unit. See Table 1 for estimates of trend and associated statistical significance.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Indiana

Fig. 3. Annual indices of abundance by year (O) and predicted population trends (solid line) for selected states and provinces in the central unit. See Table 1 for estimates of trend and associated statistical significance.

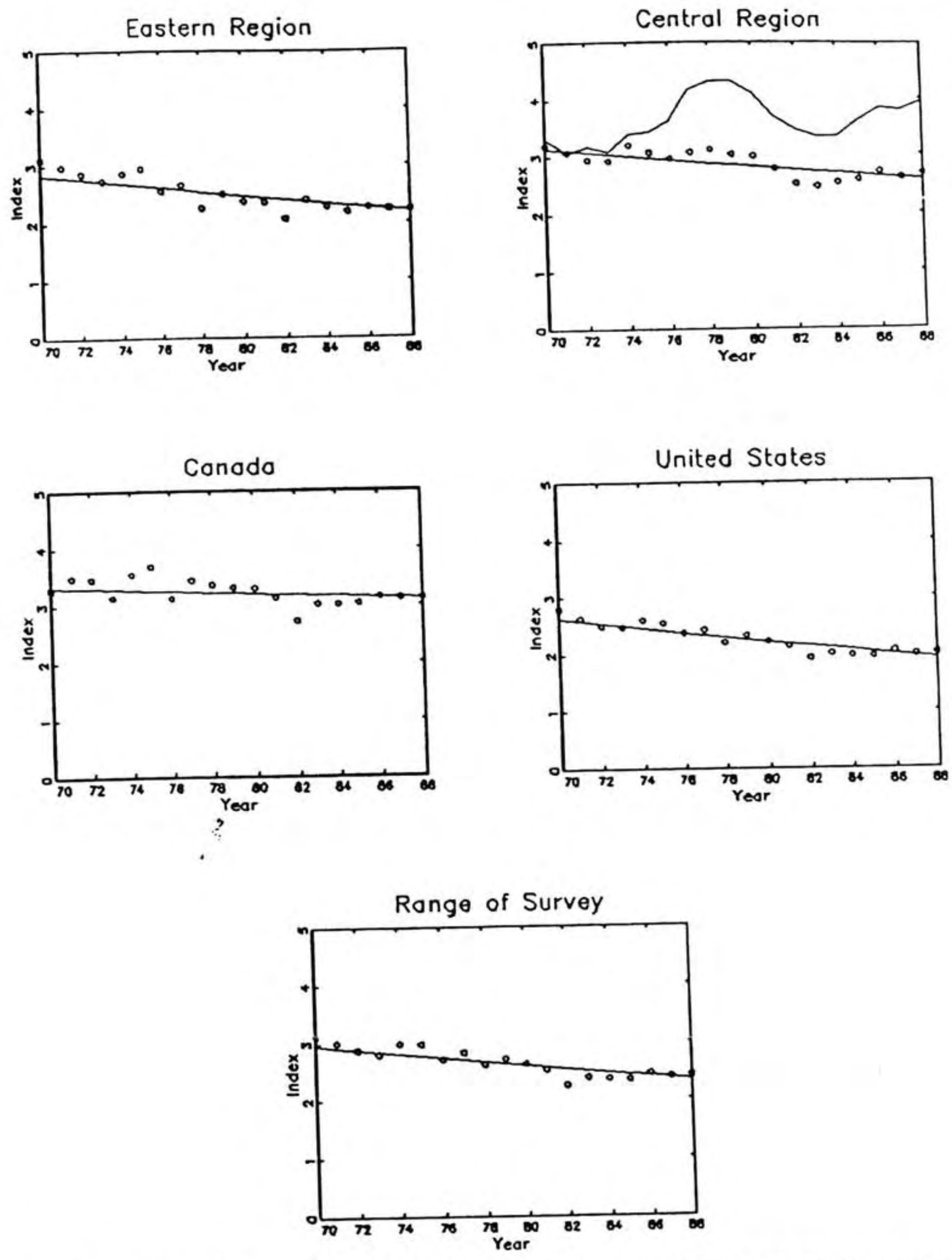

Fig. 4. Annual indices of abundance by year (O) and predicted population trends (solid line) for the eastern unit, central unit, United States, Canada, and the entire survey area. In the central unit, we included the annual indices calculated using the base year method (curved line) for comparison. See Table 1 for estimates of trend and associated statistical significance.

Table 2. Average number of years routes were conducted, the average number of observers surveying each route (standardized to observers/10 yr), and the average number of constant zero years per route by state and province, management unit, and entire survey area, 1970–88.

Region	$\bar{x}$ no. yr route conducted	$\bar{x}$ no. observers/ 10 yr	$\bar{x}$ no. constant zero routes/yr
Eastern unit			
Conn.	12.22	2.83	6.70
Me.	14.29	2.23	1.87
Md.	9.33	4.64	6.75
Mass.	12.79	1.86	3.84
N.B.	14.98	2.75	1.27
N.H.	13.78	2.53	2.33
N.J.	12.87	2.01	3.93
N.Y.	11.50	2.34	4.06
N.S.	12.67	1.95	3.86
Pa.	9.98	1.78	7.21
Prince Edward Isl.	13.17	2.66	2.75
Que.	5.49	2.45	1.19
R.I.	13.00	1.00	7.33
Vt.	13.95	3.00	1.95
Va.	12.22	2.83	6.70
W.Va.	10.47	1.88	7.80
Unit	11.18	2.39	4.42
Central unit			
Ill.	5.88	3.59	7.40
Ind.	9.40	2.94	9.12
Mich.	15.03	2.26	1.40
Minn.	10.82	3.03	3.24
Oh.	10.15	2.23	7.30
Ont.	10.65	3.11	0.76
Wis.	12.25	2.28	4.08
Unit	11.52	2.69	3.57
Entire survey	11.35	2.53	3.92

regression without observer covariable analysis. This result is a consequence of the pattern of increase then decline evident in both unit (Fig. 4), state, and province (Fig. 3) indices in the central unit. Note that base year and route-regression indices show extremely similar patterns of year-to-year change (Fig. 4, central unit) with the exception of 1976, when the base year indices predicted an increase, and 1977, when the base year predicted a much greater increase than that shown by the route-regression indices.

To further examine the patterns of population change between 1975 and 1977, we used the route-regression analysis with observer covariables to conduct a separate analysis to estimate population changes over the 3 years. This analysis predicted a 5.96% change between 1975 and 1977, whereas the change predicted by the base year indices was 21.86%. We conclude that the differences in results between the methods result primarily from the perception of a population peak in the late 1970's created by the base year results, which is not verified by our route-regression analysis.

Route Statistics

Although the trend analysis covers the period between 1970 and 1988, many routes were not run every year, and most routes were not consistently surveyed by the same observer. Both of these factors reduce the accuracy of a trend analysis by increasing the variance of the trend estimate (Geissler and Link 1988). In the singing-ground survey, states and provinces varied in both the average number of years a route was run and the rates of observer change (see below) over time. For example, in Michigan, each route was surveyed for an average of 15.0 years, whereas in Quebec, routes were surveyed for only an average of 5.5 years (Table 2). With the exception of Quebec, routes in states in the southern part of the survey were conducted for fewer years than routes in northern states and provinces. There was no difference in average number of years between eastern and central units ($P > 0.5$).

We estimated the rate of observer change as the average number of observers per 10 years on routes in each state and province. Maryland had the highest rate of observer change whereas both routes in Rhode Island were run by the same observers (Table 2). The rate of observer change was similar between eastern and central units.

Effects of Constant Zero Routes

Over the entire survey region, routes averaged about 4 years in constant zero status (Table 2). Individual states or provinces varied greatly in the number of years in constant zero status per route, from 0.8 year per route in Ontario to 11.0 constant zero years per route in Delaware (which is excluded from our analysis). The extremely low number of constant zero routes in Ontario may be due to differences in recording of constant zero routes. Routes in states in the southern portion of the woodcock range had more constant zero years than states and provinces in the north, reflecting the lower breeding densities of woodcock in the south. The average number of years in constant zero status per route was similar between the eastern and central units ($P > 0.4$).

We estimated population trends (b_i from eq 1) on each route, both including the constant zero data and excluding them (without observer covariables because constant zero data have no observers), and we found the difference between the slope estimates. There were no consistent differences for any state or province nor large regional differences in these trends (difference in eastern unit = −0.029, difference in central unit = 0.00294, overall difference = −0.0132, all not significantly different from zero; $P >$ 0.1). Weighted trend estimates derived from these groups of slopes provided virtually identical estimates of population trends.

Importance of Observer Covariables

We present F-statistics for the test that addition of the observer covariables significantly decreased the mean-squared error of the route regressions (Table 3). In most states and provinces, and overall, these results were significant, suggesting that observer covariables do reduce the overall mean-squared error in the regressions.

Trends of Other Bird Species

Seven of the 14 species of eastern birds from the breeding bird survey data (see Table 4 for scientific names) had declining population trends, but 2 of the species with significant declines, field sparrows and golden-winged warblers, use nearly the same habitat as do woodcock. The eastern region of the breeding bird survey is larger than the region surveyed in the singing-ground survey. However, examination of state and provincial trends of the 14 species indicates that the species were not declining to a greater degree in areas covered by the singing-ground survey.

Table 3. F-statistics for the test that observer differences significantly reduce the mean-squared error in the route-regressions for each state and province and for the entire survey.

State/province	F	df Numerator	 Denominator	P
Conn.	2.04	44	82	0.003
Del.	0.97	20	13	>0.5
Me.	2.42	247	686	<0.001
Md.	1.69	129	155	0.001
Mass.	1.75	62	175	0.002
N.B.	1.62	324	697	<0.001
N.H.	1.30	76	186	0.079
N.J.	2.13	51	155	<0.001
N.Y.	1.98	372	833	<0.001
N.S.	2.08	171	477	<0.001
Pa.	1.97	181	412	<0.001
Prince Edward Isl.	1.01	60	137	0.47
Que.	1.92	124	133	<0.001
Vt.	1.78	111	200	<0.001
Va.	1.20	170	282	0.087
W.Va.	1.35	140	347	0.014
Ill.	1.15	103	50	0.29
Ind.	1.61	197	245	<0.001
Mich.	2.18	634	1,611	<0.001
Minn.	2.24	402	607	<0.001
Oh.	1.63	192	401	<0.001
Ont.	1.69	572	998	<0.001
Wis.	2.67	431	962	<0.001
Entire survey	1.89	4,829	9,845	<0.001

DISCUSSION

We have shown that addition of the observer covariable reduces the mean-squared error of the route regression, and therefore including the observer covariables provides a better overall fit of the regression line for a route. However, estimating trends with observer covariables effectively reduces the number of years for each route, and hence degrees of freedom for the slope parameter, and the precision of the route slope estimate is reduced. If the population changes rapidly, as was the case in the central unit, splitting up the interval with observer covariables can greatly change the perception of overall population change because the population trend might be increasing for 1 observer but declining for others.

The differences between base year and route-regression indices emphasize the need for examining annual indices in population trend analysis. Although all analyses indicate that the population declined in the central unit between 1979 and 1983 and has generally increased after 1983, summary trend statistics for the entire period differ between methods. We probably do not have sufficient information to evaluate long-term trends in this population, because a trend is masked by short-term fluctuations in the population. By examining the annual indices, managers can evaluate the importance of short-term fluctuations in determining our perception of long-term trends.

Why Are Woodcock Declining?

Habitat Changes.—The acreage of forested land in the eastern United States generally increased in this century until the mid-1970's, after which it has declined, partially due to human

Table 4. Population trends (% change/yr) from 1966 through 1987 for 14 bird species from the North American breeding bird survey.

Species	Trend (% change/yr)	No. routes
Field sparrow (*Spizella pusilla*)	-3.52^{**}[1]	1,106
Swamp sparrow (*Melospiza georgiana*)	1.47	647
Common yellowthroat (*Geothlypis trichas*)	-0.44^{*}	1,362
Blue-winged warbler (*Vermivora pinus*)	0.36	399
Golden-winged warbler (*V. chrysoptera*)	-2.77^{**}	291
Yellow warbler (*Dendroica petechia*)	1.51^{*}	1,138
Mourning warbler (*Oporornis philadelphia*)	0.91	430
Nashville warbler (*V. ruficapilla*)	3.61	457
Chestnut-sided warbler (*D. pensylvanica*)	−0.91	699
Wilson's warbler (*Wilsonia pusilla*)	1.81	157
Traill's flycatcher (*Empidonax alnorum*)	1.29^{*}	888
Veery (*Catharus fuscescens*)	−0.72	695
Eastern bluebird (*Sialia sialis*)	−0.45	1,077
Ruffed grouse (*Bonasa umbellus*)	−2.06	465

[1] Test of the null hypothesis that trend is equal to zero. * $P < 0.05$; ** $P < 0.01$

development (Powell and Rappole 1986). Brooks and Birch (1989) indicate that although forest land acreage has remained constant in New England from 1973 to 1984, maturation has significantly decreased the acreage of early successional habitats used by woodcock. However, Owen (1977) and Gutzwiller and Wakeley (1982) related population declines to other habitat features, such as the loss of abandoned fields through succession. Also, human development in the eastern United States might have an impact on woodcock populations (Powell and Rappole 1986). Dwyer et al. (1983) analyzed habitats along singing-ground survey routes in the northeastern United States, and they concluded that declines in woodcock populations in the East were related to human development.

Habitat changes should also affect populations of other bird species that use habitats similar to those of woodcock. If these bird species were also experiencing population declines, the hypothesis of habitat change causing the population declines would be corroborated, but breeding bird survey data do not provide unequivocal evidence that early-successional species are declining. Because no species have identical habitat requirements, however, the absence of declines in this diverse group of species does not invalidate the hypothesis that habitat changes are a causal factor in woodcock declines. Woodcock are perceived on the breeding bird survey routes at very low densities because the breeding bird survey is conducted in the morning, and woodcock are only heard during stops near the beginning of the route. However, breeding bird survey trend results for woodcock indicate a range-wide decline of woodcock of −0.91%/year.

Weather Effects.—Dwyer et al. (1988) documented the effects of weather on both production and survival of young and on the number of singing males. Spring storms in 1981 and 1982 caused a decrease in the number of singing males on their study site in Maine (Dwyer et al. 1988), and population indices from the singing-ground survey also indicated low numbers of birds in many states, provinces, and regions during these years. Weather effects are often observed in roadside survey results (Robbins et al. 1986), and the singing-ground survey results intimate that severe storms in spring play a role in mortality of woodcock.

Effects of Hunting.—The singing-ground survey results cannot be directly related to changes in mortality associated with woodcock hunting. Limited banding analyses indicate that hunting mortality is not a major component of overall mortality (Dwyer and Nichols 1982), and success has generally been declining among woodcock hunters (J. B. Bortner, American Woodcock Harvest and Breeding Population Status, USFWS, Laurel, Md., 1988).

MANAGEMENT IMPLICATIONS

This analysis reemphasizes that woodcock are declining in the eastern United States and Canada and indicates that woodcock populations in the central part of the continent, although undergoing more fluctuations over the period 1970–88, are also experiencing recent population declines. Unfortunately, survey data are often of limited use in evaluating the causes of gradual population changes (Sauer and Droege 1990), especially when little information exists on regional variation in the factors that might be associated with population changes. Both additional information on regional changes in woodcock habitat and detailed studies of habitat-specific survival on breeding and wintering areas are needed.

Information from earlier studies can be used to identify factors that affect local populations of woodcock. Habitat changes and weather fluctuations have been implicated as causal factors in the decline (Dwyer et al. 1983), but the effects of hunting on woodcock populations are not clear (Dwyer and Nichols 1982). Degradation of wintering habitat in both eastern and central parts of the range is also cause for concern. Continued population monitoring, in conjunction with better information on regional habitat changes and additional studies of the possible limiting factors, should provide insight into what factors are most important in affecting population changes in woodcock.

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Received 5 October 1989.
Accepted 13 December 1990.
Associate Editor: Brooks.

EFFECTS OF NEST INSPECTIONS AND RADIOTAGGING ON BARN OWL BREEDING SUCCESS

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Abstract: I examined the effect of frequent visits to barn owl (*Tyto alba*) nests by comparing nests subject to regular inspection from before laying to fledging with nests that were visited only immediately before fledging. I found no differences in the mean number of young fledged or in the mass of young at fledging. Nest visits did not encourage birds to change their nest sites in subsequent years. No difference in breeding performance was found between pairs that carried tail-mounted radio transmitters and pairs that did not.

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Examining nests to determine laying date, clutch size, growth rates, and the number of young fledged is necessary in detailed population studies of birds. Additionally, the adult birds are often caught and marked. There are risks in some species that nest inspection and adult capture may affect the survival of adults as well as their reproductive success (Steenhof and Kochert 1982). For many species there is anecdotal information on the effects of detailed study but objective assessments are few, and variation in sensitivity among species is apparent (Grier 1969, Willis 1973, Parsons and Burger 1982). Similarly, the effects of radiotagging seem to vary, although it can be difficult to separate the effects of capture and handling from those of carrying transmitters (Lance and Watson 1977, Warner and Etter 1983).

I assessed the effects of frequent nest visits and radiotagging on the breeding performance and site fidelity of barn owls. This species has undergone widespread population declines in much of North America and Western Europe in response to changing agricultural practices (Braaksma 1980, Colvin 1985, Marti 1988), and intensive study is needed to develop effective conservation measures. Shawyer (1987) asserted that barn owls are sensitive to human disturbance, particularly during the early stages of breeding, but did not provide field evidence.

I am most grateful to Buccleuch Estates, the Economic Forestry Group, the Forestry Commission, and to numerous farmers for permission to study barn owls on their land. Thanks also to I. Newton, M. Marquiss, S. Wanless, T. Irving, I. K. Langford, P. Bell, F. Slack, S. G. Abbott, M. Osborne, J. Young, R. Smith, and R. Rose for their assistance. Funding was provided by the Natural Research Council, Nature Conservancy Council, World Wide Fund for Nature, and the University of Edinburgh.

STUDY AREA

The study was carried out in Dumfriesshire, southern Scotland. At altitudes between sea level and 200 m, the area is farmed mainly for dairy and livestock production, creating a landscape of enclosed, improved pastures and numerous small woodlands. At higher altitudes, sheep production predominates over open, unfenced rangeland supporting native vegetation. Sections of this rangeland have, in recent years, been subject to large scale reforestation involving exotic conifers such as Sitka spruce (*Picea sitchensis*). Barn owls nested mostly in abandoned farm buildings and in nest boxes. Voles