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POPULATION TRENDS OF SOME NORTHEASTERN NORTH AMERICAN LANDBIRDS: A HALF-CENTURY OF DATA

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ABSTRACT.—We analyzed population trends of 26 species of North American migratory landbirds using 53 years of spring migration count data collected in eastern Massachusetts from 1937 to 1989, inclusive. These data span twice the time period of most landbird monitoring data sets, allowing us to examine how accurately trends based on shorter-term investigations of population trends represent longer ones. We found that 18 species (64%) have declined significantly, three species (12%) have increased significantly, and five species (19%) have shown no trend over this time period. Using the most recent ten years of our data, the trend matched that of the full 53-year data set for 10 species (38%). Using the most recent 20 years of data, the number of matching trends increased to 18 (69%). Using a 30-year subset of data did not improve the percentage of matching trends and showed a greater number of non-significant trends than did analysis of the most recent 20-year subset of data. This pattern resulted because many species appeared to be at low population levels in the 1950s and early 1960s, before the time when most current avian censuses and surveys began. Our results indicate that many species are in fact declining, but that declines in the past 20 years might be partly a result of normal, shorter-term population fluctuations. *Received 24 Aug. 1990, accepted 28 Nov. 1990.*

There is increasing concern that populations of many North American migrant bird species are declining (Robbins et al. 1989, and see review in Askins et al. 1990). Because of the relatively restricted winter ranges of many Neotropical migrant species (Rappole et al. 1983), the habitat specificity of some, and the recently accelerated rate of tropical deforestation (cf. Gradwohl and Greenberg 1988), concern has centered on those species that breed in North America but winter in Central or South Amer-

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The Variable Screech-Owl (*Otus atricapillus*) and its relatives. See special ornithological literature review by Marshall, Behrstock and Konig, p. 311. Painting by Joe T. Marshall.

ica (e.g., Terborgh 1989). Effects on breeding season biology imposed by forest fragmentation in North America have also been implicated in causing declines in these species (e.g., Whitcomb 1977, Whitcomb, B. L. et al. 1977, Whitcomb, R. F. et al. 1981, Robbins 1980, Lynch and Whigham 1984, Askins and Philbrick 1987, Askins and Sugeno 1987). Reproductive success of many forest-dwelling migrant passerine species is reduced near forest edges as a result of increased predation (Wilcove, 1985a, b; Small and Hunter 1988) and parasitism by Brown-headed Cowbirds (*Molothrus ater*) (Mayfield 1977, Brittingham and Temple 1983). Although the amount of forested land in the eastern United States in recent decades has remained stable, or slightly increased in some areas (Terborgh 1989, Birch, unpubl. data), existing forest has become increasingly fragmented because of roads and urbanization (Terborgh 1989).

Recognizing these major, broad-scaled changes in habitat, researchers have attempted to monitor migrant bird populations in North America so that predictions can be made about future population levels and so that species or species groups of critical concern can be identified. Studies have relied on data from the U.S. Fish and Wildlife Service's Breeding Bird Survey (see Robbins et al. 1986), numerous breeding bird censuses (Johnston and Winnings 1987, Holmes and Sherry 1988), or on migration counts or captures (Hussell 1981, Jones 1986, Stewart 1987, Hagan et al., in press, Hussell et al., in press). Some studies have recently documented declines in some migratory species (e.g., Holmes and Sherry 1988, Robbins et al. 1989), but most are subject to criticism because they are based on only about 20 years of data and therefore might not represent long-term trends. Many bird populations show natural fluctuations at this temporal scale. For example, reproductive success of many warbler species that breed in the boreal forest is substantially increased as a result of spruce budworm (*Choristoneura fumiferana*) outbreaks (Kendeigh 1947, MacArthur 1958, Morse 1978, Harrison 1984), a major food of many migrant passerine warblers during the breeding season. Recent declines reported by some studies might be a consequence of elevated population levels in early and mid-1970s when there was a massive outbreak of the spruce budworm in the northeastern United States and Canada (Hardy et al. 1981). That is, man-induced habitat change in the Neotropics or the Nearctic might not be the cause for recent declines. Unfortunately, data on populations prior to the mid-1960s are rare.

In this paper we analyze population trends of 26 Nearctic-Neotropical migrant landbird species using spring migration census data collected over a 53-year period (1937–1989) in eastern Massachusetts. This data set is unusual in its completeness and duration. It provides an opportunity to examine population changes of some species for over half a century, and

therefore allows us to investigate how accurately trends based on shorter-term data represent longer ones. By using temporal subsets of the full data set, we also estimate how many years of data would have been needed before long-term population trends would have been revealed (those obtained by the full data set), and we show that shorter periods of census data can be misleading.

METHODS

Our data come from the field notes of N. P. Hill and from those of the late Ludlow Griscom (Assistant Curator of Ornithology and Research Ornithologist, Museum of Comparative Zoology, Harvard University). From the 1930s until his death in 1959, Griscom was an acknowledged leader in field ornithology; his notes are currently deposited in the Peabody Museum in Salem, Massachusetts. The raw data are counts of birds seen in the field during spring migration in May in Middlesex and Essex counties in eastern Massachusetts. Specific sites within these counties were visited each year between 1937 and 1989. Middlesex county sites routinely visited included the towns of Cambridge (especially Mt. Auburn cemetery, a well-known "birding" location during migration), Arlington, Belmont, Lexington, Concord, and Wayland. In Essex County, sites were located in a strip of countryside from Lynnfield and Nahant north to West Newbury, Newburyport, and Plum Island. Hill collected data at these sites from 1940–1946, and then from 1952–1989; he was absent from the state from 1947–1951. L. Griscom collected data from 1937–1958, although illness prevented field work by him in 1956. Thus, the two data sets collected in the same locations overlap in the 1950s.

These data were recorded by the observers, mostly on intensive "birding" excursions, often from pre-dawn to after dark. Bird sightings were recorded in field notebooks at the time of sighting, and records of hours of effort were always kept. However, because sampling did not follow a prescribed protocol, several sources of undesirable variation were imposed on annual population estimates. For example, the number of hours spent in the field varied among years. Hill spent from 7–103 h (\bar{x} = 28.8 h, N = 45 years) and Griscom spent from 37–108 h (\bar{x} = 79.3, N = 21 years) per year in the field. Also, which days were spent in the field varied from year to year, although we used only sampling days in May when migration is at a peak in southern New England. No effort was made to be in the field only when certain weather conditions prevailed, and each excursion usually lasted an entire day. Furthermore, because observers were in the field for only a few days each May, migration "fall outs" (migration interrupted by weather or other factors) could cause inflated counts if observers happened to be in the field on those days.

Some effects of these sources of variation can be minimized through analysis. First, to accommodate annual variation in effort, the number of birds of each species seen each May was converted to the number seen per hour of field observation. Because of the high variability in annual counts, partly owing to weather and partly to stochastic features of migration, we calculated population indices using a 5-year moving average. Each of the five years was given equal weight in the calculation of the moving average. Finally, for the purposes of documenting long-term trends, the temporal extent of the data set tended to overcome these sources of variation.

Local environmental and habitat change was not quantified during the study, but some change was evident. There was no general urbanization or major change in wetlands in areas censused, but some loss of agricultural area and some increase in suburban residential area was apparent. Some pastureland was lost to residential growth in the towns of Lexington, Concord, Wayland, Lynnfield, and West Peabody and to industrial growth in the Newbury-

port area. There was a general loss of brush and second-growth habitats, and forests became more fragmented but without a substantial overall loss of area. In some areas, habitat improved with the creation of the Great Meadows Wildlife Refuge in Concord and the Parker River Refuge on Plum Island.

We analyzed population trends of 26 Neotropical migrant species and two temperate, resident species, although for only 14 species did we have both Griscom and Hill data. Data from Griscom's field notes were useful only for this subset of species recorded by Hill because Griscom was primarily interested in uncommon species sightings. He often wrote that numbers were "normal" or that a species was "fairly common." We used his data only for those species in which he recorded the actual number of individuals observed. If Griscom records were available for a species, 53 years of continuous data (49 smoothed points) were available for analysis (1937–1989). With Hill data alone, 38 years of continuous data (34 smoothed points) were available (1952–1989), with an additional seven years of data which were collected from 1940–1946.

To assess population trends over this half-century of time, and to assess how much data might be needed to reveal the same trend as observed for the full data set for each species, we analyzed the trends using only the most recent ten years of data, then the most recent 20, 30, and 40 years, and finally the entire data set. We operationally defined the "long-term" trend for each species as the one revealed by the entire data set. For each increment of data, we performed simple linear regression on the \log_e of the smoothed data points, and used the slope of the regression to calculate a percent annual change during that period, following the methods described by Holmes and Sherry (1988). We used the *P*-value of the regression to determine the significance of population change. Two data points were sacrificed on either end of the regression because of the 5-year smoothing function. We did not include the disjunct data from 1940–1946 collected by Hill in regressions because, after smoothing, it provided only three data points, and without Griscom data to span the gap in the Hill data, these three points could unduly influence the slope and significance of the regression.

A word of caution is warranted concerning regression *P*-values. Using regression to document significant population trends is inherently biased because data points are not independent. For example, two data points close in time are more related than two points far apart in time. A large population in one year can lead to several years of high population indices. Smoothing data can exacerbate this problem. However, smoothing also tends to produce more realistic annual population indices because of the many sources of annual variation in migration counts unrelated to real population change (weather, varying migration routes, etc.). We have sacrificed independence for realism. Smoothing can either enhance or reduce statistical significance; thus, we regard calculated *P*-values as only indices of significance of population change. Because all data were treated identically, lower *P*-values should represent greater significance, albeit inexact representations.

RESULTS

For 12 Neotropical migrant species, 38 years of data were available for analysis and for 14 species, 53 years of data were available (Table 1). Using all data for each species, we found that 18 species (69%) have declined significantly and three species (12%) have increased significantly in numbers (Table 2). Five species (19%) showed no significant change.

Using the most recent ten years of data (smoothed points 1978–1987), trends matched those of the full data set for ten species (38%) (Table 1). Using the most recent 20 years of data, the percent of matching trends

increased to 69%. Using 30 years of data, the percent of trends that matched the full data set (62%) did not improve over the percent observed for the 20-year data subset. For the 12 species with 38 years of data (34 smoothed points), the “40-year” trend was, by definition, correct. For the remaining 14 species with 53 years of data (49 smoothed points), 12 (92%) matched the long-term trend using the 40-year data subset. Trends in 19 of all 26 species (73%) failed to match their long-term trend for at least one time interval.

The 10-year subset of data showed 14 (54%) non-significant trends, whereas the 20-year subset showed only six (23%) (Table 2). The 30-year subset of data showed 14 (54%) non-significant trends, the same as the 10-year subset (Table 2). Plots of population indices for individual species indicate why this pattern was evident (Fig. 1). Population levels of many species were elevated in the 1968–1977 time period, and low in the 1978–1987 period, which caused many significant negative trends (and few non-significant trends) in the last 20 years of data. Populations of many species also tended to be at low levels in the late 1950s and early 1960s. Thus, when we included 1958–1967 data (the 30-year subset), many trends became non-significant, rather than significant, and negative. The last four decades of data combined showed only seven nonsignificant trends, and 17 of the 21 significant trends were negative (Table 2). Thus, the 40-year data set showed many of the negative trends revealed by the shorter, 20-year subset.

Considering both statistically significant and non-significant population trends, the most recent decade of data showed a mean change per year of -2.2% . Using the 20-year data set, the mean annual change was -2.0% . With 30 years of data, the subset that showed many non-significant trends, the mean annual change decreased to -0.86% per year. The mean annual rate of decline increased to -1.1% using the 40-year subset and to -1.2% using all available data (34 smoothed points for 12 species and 49 points for 14 species). The rate of change varied from $+0.7\%$ (Bay-breasted Warbler) to -3.8% (Least Flycatcher) (see Table 2).

These results also show a cyclic nature of population change for some species. Visual inspection of the graphs (Fig. 1) reveals information about trends that is difficult to obtain quantitatively. Various patterns in population change are evident, including: (1) cyclic change with no long-term trend, (2) cyclic change with slow overall decline, (3) cyclic change with an overall increase, (4) long, linear decline, and (5) linear increase. Species that showed cyclic trends typically had two or three pronounced peaks in abundance during the entire time span. Consistent long-term declines were found in species with both cyclic and linear patterns of change. We defined a consistent long-term decline as one that showed a significant

TABLE 1

ANNUAL RATE OF POPULATION CHANGE (PERCENT PER YEAR) FOR 28 SPECIES BASED ON 49, 40, 30, 20, AND 10 "SMOOTHED" YEARS OF DATA. THE OVERALL TREND ("TREND" COLUMN) IS BASED ON THE MAXIMUM AVAILABLE DATA FOR A SPECIES

Common name	Scientific name	Trend ^b	Years of data ^a				
			49	40 ^c	30	20	10
Least Flycatcher	<i>Empidonax minimus</i>	--	-3.1**	-3.8**	-2.8**	-2.9**	ns
Great Crested Flycatcher	<i>Myiarchus crinitus</i>	-	x	-0.9**	ns	ns	+3.2**
Tufted Titmouse	<i>Parus bicolor</i>	++	x	+2.6**	+2.8**	+4.3**	+2.5**
Swainson's Thrush	<i>Catharus ustulatus</i>	-	-1.6**	-2.0**	ns	ns	ns
Red-eyed Vireo	<i>Vireo olivaceus</i>	ns	x	ns	ns	ns	-3.9**
Blue-winged Warbler	<i>Vermivora pinus</i>	++	x	+0.5**	+0.6**	+1.0**	+2.1**
Golden-winged Warbler	<i>V. chrysoptera</i>	--	-1.4**	-1.4**	-1.4**	-0.8**	ns
Tennessee Warbler	<i>V. peregrina</i>	+	x	+1.6**	+1.3*	ns	ns
Nashville Warbler	<i>V. ruficapilla</i>	--	-1.9**	-2.0**	-1.2**	-0.7*	ns
Northern Parula	<i>Parula americana</i>	ns	ns	ns	ns	-4.7**	-7.5**
Chestnut-sided Warbler	<i>Dendroica pensylvanica</i>	--	-1.2**	-1.6**	-1.4**	-2.4**	ns
Magnolia Warbler	<i>D. magnolia</i>	--	-2.4**	-3.2**	-2.6**	-3.6**	ns
Cape May Warbler	<i>D. tigrina</i>	-	-0.2*	ns	ns	-1.9**	-1.6**
Black-throated Blue Warbler	<i>D. caerulescens</i>	-	-1.0**	-1.3**	ns	-4.5**	ns
Black-throated Green Warbler	<i>D. virens</i>	-	x	-1.1*	ns	-2.3*	-8.0**
Blackburnian Warbler	<i>D. fusca</i>	ns	x	ns	ns	-2.5**	-2.3*
Bay-breasted Warbler	<i>D. castanea</i>	+	+0.7**	ns	ns	-5.0**	ns
Blackpoll Warbler	<i>D. striata</i>	-	-1.3**	-1.2**	ns	ns	ns
Black-and-white Warbler	<i>Mniotilta varia</i>	-	x	-1.6**	ns	-4.2**	-10.3**
American Redstart	<i>Setophaga ruticilla</i>	-	x	-1.7*	ns	-1.7**	ns
Ovenbird	<i>Seiurus aurocapillus</i>	--	x	-2.2**	-1.8**	-3.1**	-7.1**

TABLE 1
CONTINUED

Common name	Scientific name	Trend ^b	Years of data ^a				
			49	40 ^c	30	20	10
Northern Waterthrush	<i>S. noveboracensis</i>	—	—0.8**	—0.8**	—0.7**	—1.2**	—1.5**
Wilson's Warbler	<i>Wilsonia pusilla</i>	—	—0.5**	—0.8**	—1.4**	—2.5**	—0.7*
Canada Warbler	<i>W. canadensis</i>	—	—1.5**	—1.8**	—1.8**	—2.2**	—4.0**
Scarlet Tanager	<i>Piranga olivacea</i>	ns	x	ns	ns	—3.2**	ns
Northern Cardinal	<i>Cardinalis cardinalis</i>	+	x	+3.1**	+3.3**	+3.8**	ns
Rose-breasted Grosbeak	<i>Phoeucticus ludovicianus</i>	ns	x	ns	ns	ns	ns
Northern Oriole	<i>Icterus galbula</i>	—	x	—1.2**	—1.3**	—1.3*	ns

^a *** indicates $0.01 > P < 0.05$, and ** indicates $P < 0.01$ for linear regression model, "ns" indicates no statistical significance, "x" indicates data not available.

^b "—" or "+" indicates that the same significant trend was detected for at least four time intervals. "—" and "+" indicate that the long-term trend was significantly positive or negative.

^c Only 34 "smoothed" data points available for 14 species with "x" in "49" year column.

TABLE 2

SUMMARY OF LINEAR REGRESSION ANALYSES ON SUBSETS OF THE SMOOTHED DATA. A TREND WAS DEEMED SIGNIFICANT IF THE *P*-VALUE FOR THE REGRESSION WAS LESS THAN OR EQUAL TO 0.05. THE TWO TEMPERATE RESIDENT SPECIES ARE NOT INCLUDED IN THE TABULATION

Parameter	Number of years					
	All	49 ^b	40 ^c	30	20	10
Number (+) trends	3	1	2	2	1	2
Number (–) trends	18	12	17	10	19	10
Number n.s. trends	5	1	7	14	6	14
Number matching trends ^a	26	14	24	17	18	10
Percent matching trends ^a	100	100	92	65	69	38
Number species	26	14	26	26	26	26

^a “Matching” means the same as the trend of the full data set.
^b Only those species with 49 smoothed years of data.
^c Only 34 smoothed points for 12 species (see Table 1).

negative slope for at least four of the component regression time periods (see Table 1). Nine species (scientific names in Table 1) showed such declines: Least Flycatcher (Fig. 1a), Golden-winged Warbler (Fig. 1g), Nashville Warbler (Fig. 1i), Chestnut-sided Warbler (Fig. 1k), Magnolia Warbler (Fig. 1l), Ovenbird (Fig. 1u), Northern Waterthrush (Fig. 1v), Wilson’s Warbler (Fig. 1w), and Canada Warbler (Fig. 1x). The plot of the Wilson’s Warbler trend (Fig. 1w) does not visually convey the long-term pattern of decline indicated by the statistical analysis. The consistent negative slope derived from the successive regression analyses was caused by the very low counts during the last decade, which significantly influenced each regression. Two other species also have shown a notably precipitous decline in the last decade: Black-throated Green Warbler and Black-and-white Warbler. Only one Neotropical migrant species showed a long-term consistent increase (at least four regressions with a significant positive slope): Blue-winged Warbler. The Northern Cardinal and Tufted Titmouse, two resident species, also showed clear increases in numbers (Table 1).

The methods of data collection used in this study were not as standardized as more conventional methods of bird population monitoring, such as the Breeding Birds Survey (Robbins et al. 1986), Breeding Bird Censuses (cf. Askins et al. 1990), or migration captures or counts (Hussell 1981). However, trends of selected species indicate that our data reflect real population changes. The Northern Cardinal and the Tufted Titmouse both showed strong increases in numbers (Fig. 1c and 1z, respectively) that coincided with the well-documented expansion of these two species

into southern New England (Beddall 1963, Laughlin and Kibbe 1985). We also showed that the Blue-winged Warbler (Fig. 1f) steadily increased, while during the same time period the Golden-winged Warbler (Fig. 1g) decreased. The range changes of these two species, presumably because of the more general habitat requirements of the Blue-winged Warbler, is also well-known (Confer and Knapp 1979).

DISCUSSION

The present data set allowed us to distinguish between short-term (<20 years) and very long-term (30–50 years) patterns of population change. For example, Robbins et al. (1989), using data from 1966–1987, reported significant population declines in Neotropical migrants. Using a subset of our data from 1966–1989 (smoothed points 1968–1987), we showed similar trends for the same species. However, by inclusion of data from the decade prior to this time, many of these significant declines became non-significant (e.g., see Fig. 1j, Northern Parula; Fig. 1m, Cape May Warbler; Fig. 1n, Black-throated Blue Warbler; Fig. 1o, Black-throated Green Warbler; Fig. 1p, Blackburnian Warbler; Fig. 1q, Bay-breasted Warbler; Fig. 1s, Black-and-white Warbler; Fig. 1t, American Redstart; and Fig. 1y, Scarlet Tanager). This was because the populations of many species appear to have been at low levels prior to the sampling period of Robbins et al. (1989). Thus, some of the declines they reported might have been because of natural downturns in populations after naturally induced population increases in the first decade of their study, rather than declines caused by human-induced habitat loss.

However, our results support the contention that many Neotropical migrant species are declining in abundance. Despite the lack of many trends using our 30-year subset of data, when we used the entire data set most of the significant negative trends reappeared that were revealed with the shorter-duration subsets of data (see Table 1). Negative trends for some species with high population levels in the 1970s and low levels in the 1980s “happened” to correlate with the full data set because the long-term pattern of change was also negative. However, the mechanisms which caused these two negative trends were probably different. If the species that showed cyclical patterns of change had been entering a phase of natural increase in the most recent decade, conclusions of recent, shorter-term studies (e.g., 20 years of data) might have been different. For example, if the spruce budworm outbreak had been in the 1980s instead of the early 1970s, patterns of increase in many species might have generated less concern for conservation. Because of the long duration of our data set, we have been able to place these short-term, but statistically significant changes, in perspective. Any future patterns of increase shown by some

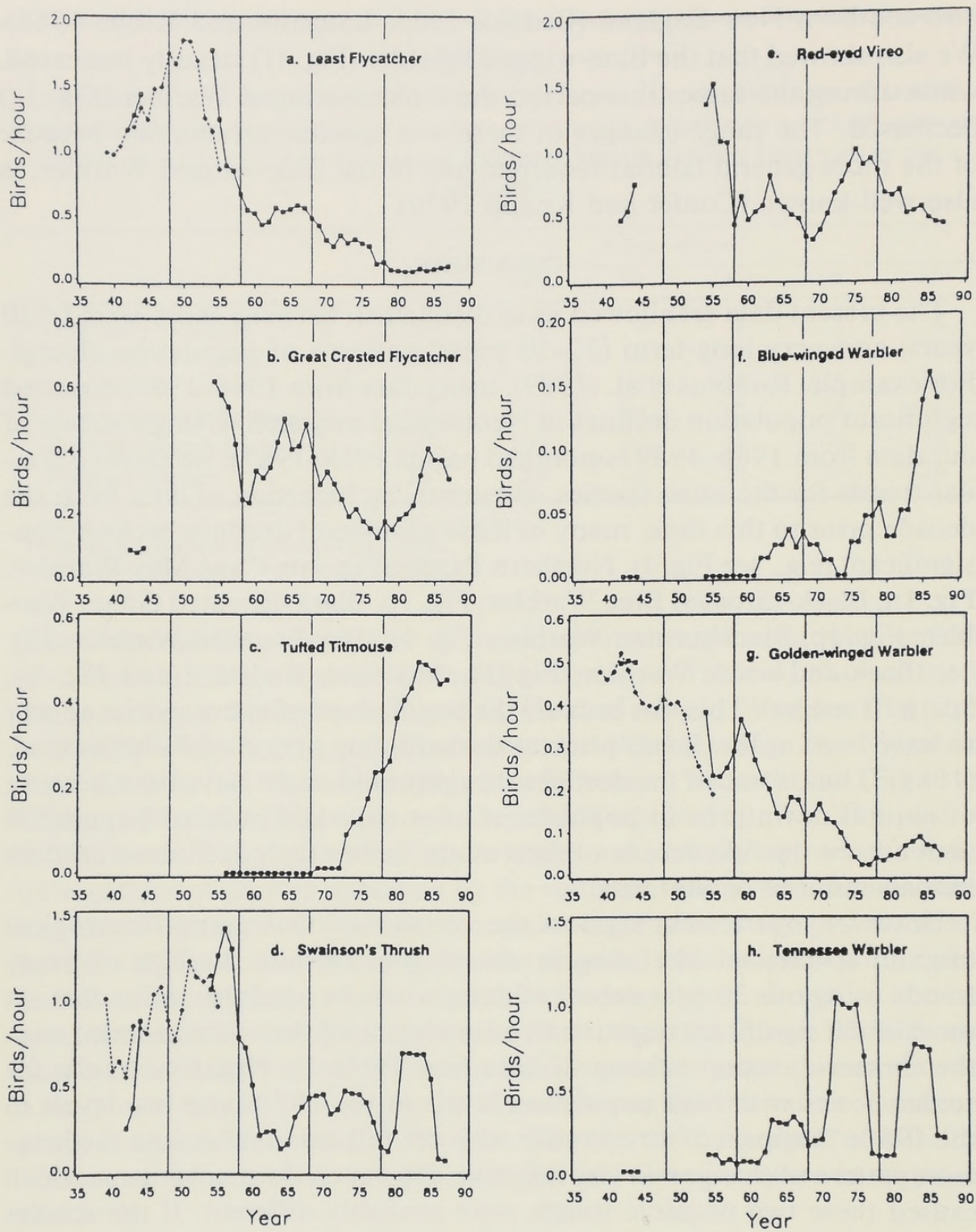


FIG. 1. Plots of population trends of 26 Neotropical migrant species and two temperate, resident species. Solid lines connecting squares represent data points derived from census data collected by N. P. Hill, and dashed lines connecting diamonds represent data points derived from L. Griscom data. Each point represents the moving average for five equally weighted years of data.

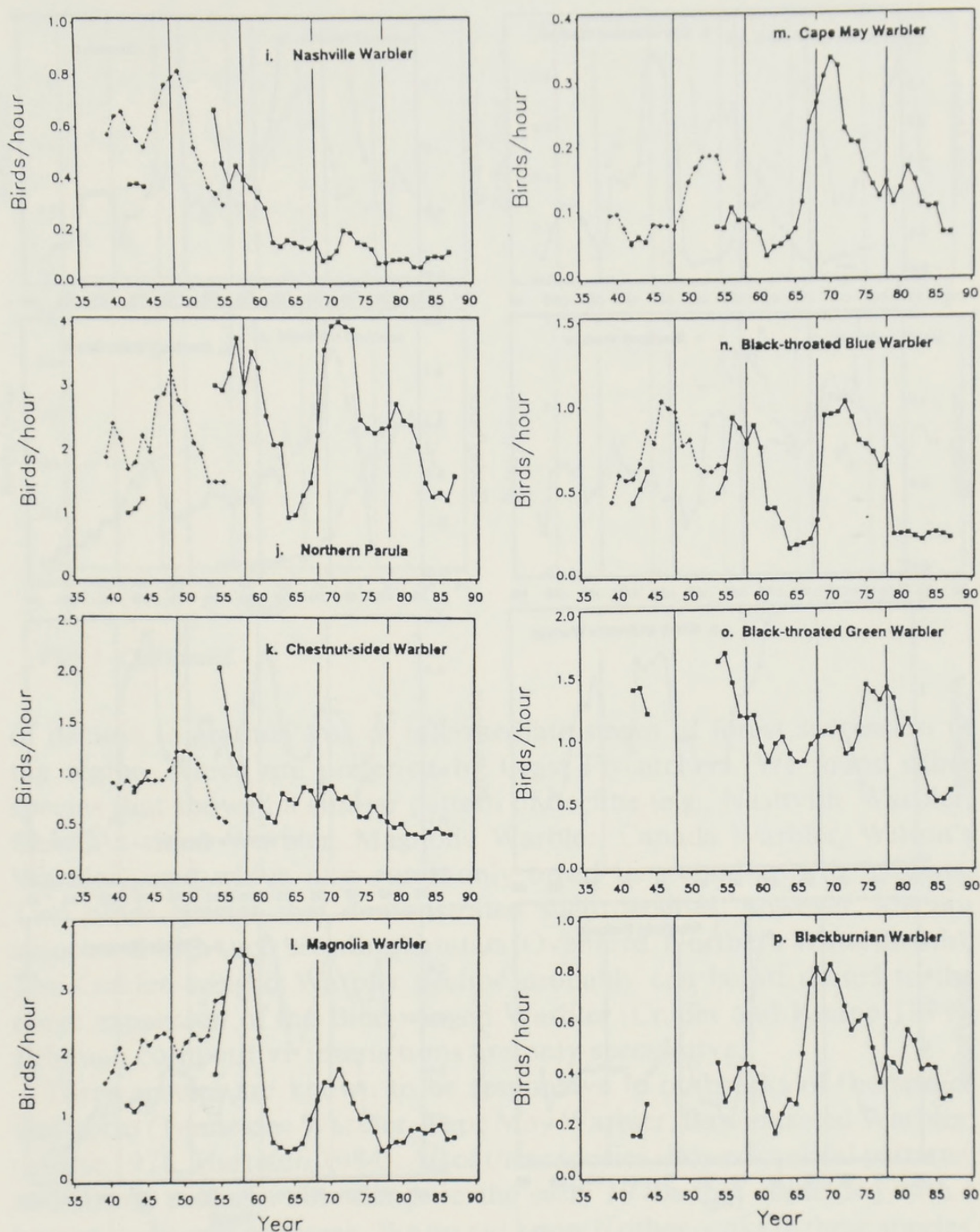


FIG. 1. Continued.

species will not warrant dismissal of conservation concerns. Rather, it should be recognized that some populations will naturally cycle; our concern is that the fundamental long-term population trend is negative and significant for most species.

Why some species showed a switch in trend direction or significance

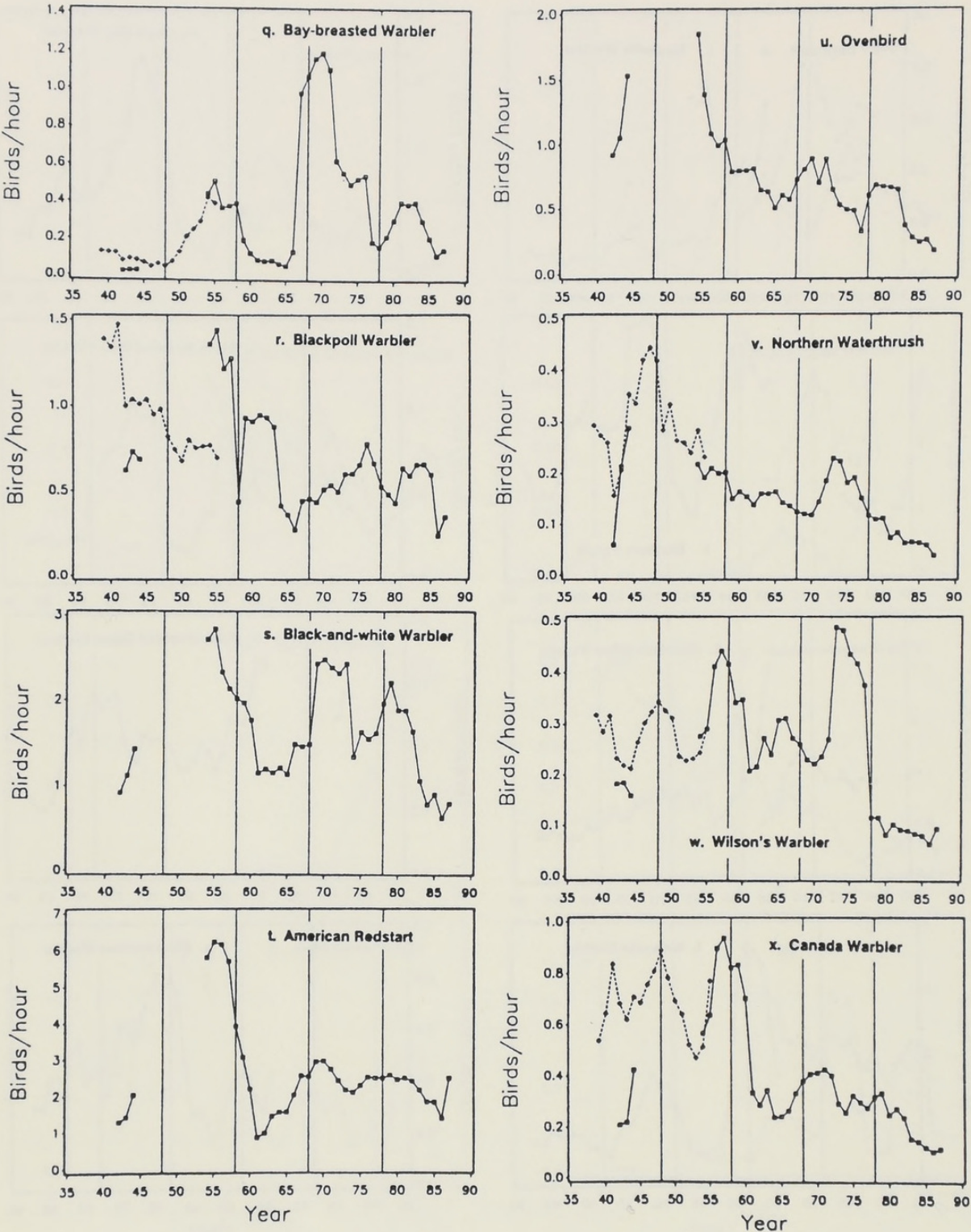


FIG. 1. Continued.

and others showed steady, monotonic declines is not known. The Least Flycatcher, which showed a consistent decline since about 1950 in our data set, also showed a consistent decline at the Hubbard Brook Experimental Forest in New Hampshire since 1969, when censuses began there (Holmes and Sherry 1988). Holmes et al. (1986) attributed this pattern

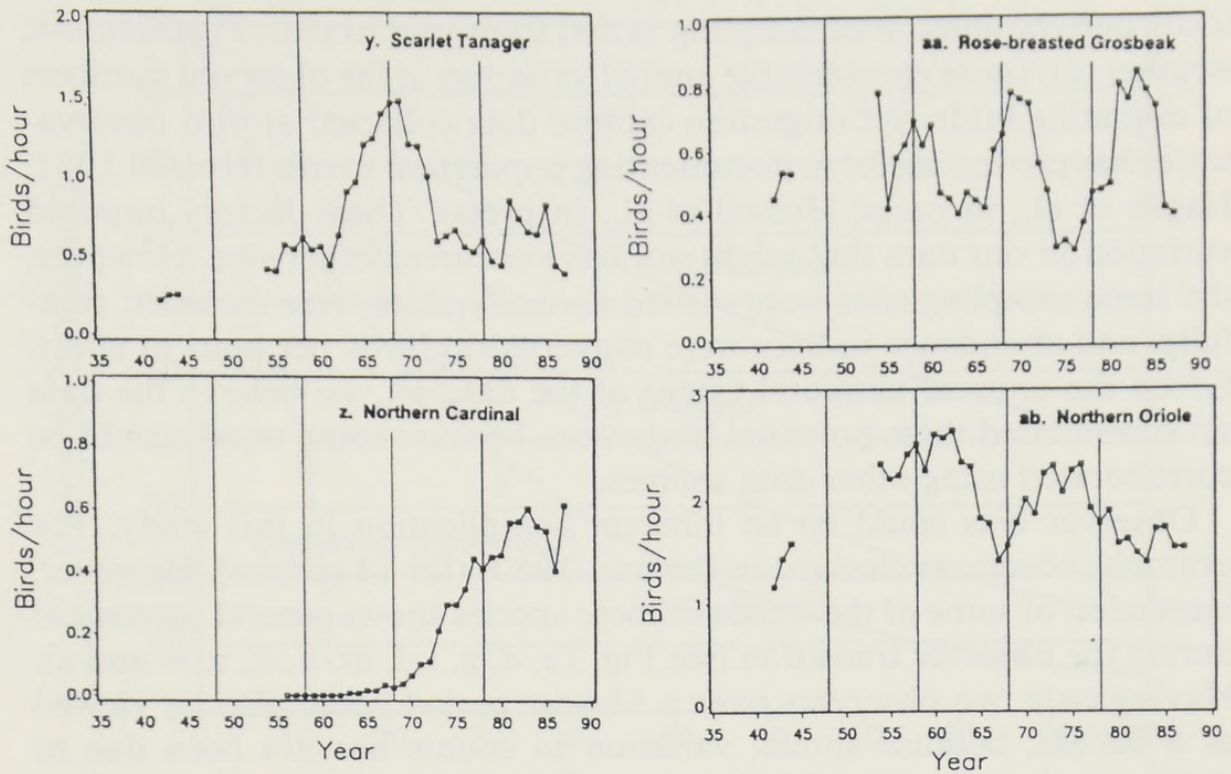


FIG. 1. Continued.

of decline to gradual loss of intermediate stages of forest succession in the region, which are preferred by Least Flycatchers. We found other species that showed a similar pattern of decline (e.g., Nashville Warbler, Chestnut-sided Warbler, Magnolia Warbler, Canada Warbler, Wilson's Warbler), and which also commonly breed in second-growth habitats. Two other species that demonstrated such declines, however, are not associated with such breeding habitats (Ovenbird, Northern Waterthrush). The Golden-winged Warbler decline probably can be attributed to the range expansion of the Blue-winged Warbler (Confer and Knapp 1979), although competitive interactions are only speculative.

Three species are known to be responsive to outbreaks of the spruce budworm (Tennessee Warbler, Cape May Warbler, Bay-breasted Warbler) (Morse 1978, Harrison 1984). All of these species showed cyclical patterns, and strong peaks in abundance in the early 1970s that coincided with a known budworm outbreak. We do not know if other peaks in these species' trends (see Figs. 1h, m, q) can be attributed to insect outbreaks. Several other warbler species also showed peaks in abundance in the early 1970s that might have been a response to the spruce budworm outbreak across southeastern Canada and the northeastern United States, even though they are not known to be "budworm" species.

The nature of our data set presents some limitations in interpretation. The data were not collected using a standard, recognized sampling pro-

tol, and the amount of sampling varied from year to year. Furthermore, weather can cause considerable annual variation in the observed numbers of migrating birds, yet migration capture data collected at bird observatories has proven useful in documenting population trends (Hussell 1981, Hagan et al., in press, Hussell et al., in press). These factors imposed variation in our data that might not have occurred otherwise. However, the same sampling sites were visited annually, data were recorded carefully, and abundance indices were converted to birds per hour of effort. Given the unusual temporal extent of the data set, we believe the data set surmounted these potential limitations because some trends could be corroborated using other data sources.

Observer bias could be an inherent complication in this study. For example, observers changed in the mid-1950s (for 14 species). However, inspection of some of the trends of these species shows general agreement during the observer transition (see Fig. 1a, d, g, i, l, m, n, q, v, w and x). Having only two observers over a 53-year period could also be viewed as a benefit, because annual variation in counts has not been due to differences in observer skill. Moreover, both observers were highly skilled from the start of sampling. Griscom's health was failing in the late 1950s and could partially explain the discrepancies. Also, because the two observers were sampling on different days during the period of overlap, perfect agreement cannot be expected. Hill's hearing was tested by audiometry in 1991 and found to be normal. Thus, it is unlikely that hearing loss has affected our results. Moreover, many declines have been apparent for 20 or more years, and most birds were detected during migration censuses by sight and not sound.

If our data represent real population changes, rates of decline are distressing. Of the 26 Neotropical migrant species we studied, 18 have declined significantly over the past 40 to 50 years. For most species, the decline has not been limited to the past 20 years, and the long-term rate of change for all 26 Neotropical migrants averaged -0.94% per year. This rate of decline would put the "average" species now at 62% of population levels of 50 years ago (Fig. 2). An annual rate of decline of -2% per year and -3% per year, which some species showed, would put their populations at 37% and 21%, respectively, of levels of 50 years ago (Fig. 2). Ignoring species divisions, and using the 38 years of Hill data alone (34 smoothed points, 1954–1987), the number of Neotropical migrants seen per hour of effort in 1987 was only 36% of the 1954 value (Fig. 2). This rate of decline was more extreme than the average rate because the distribution of rates was not normal. That is, more abundant species declined at disproportionately higher rates.

As with any migration count index of population change, it is difficult

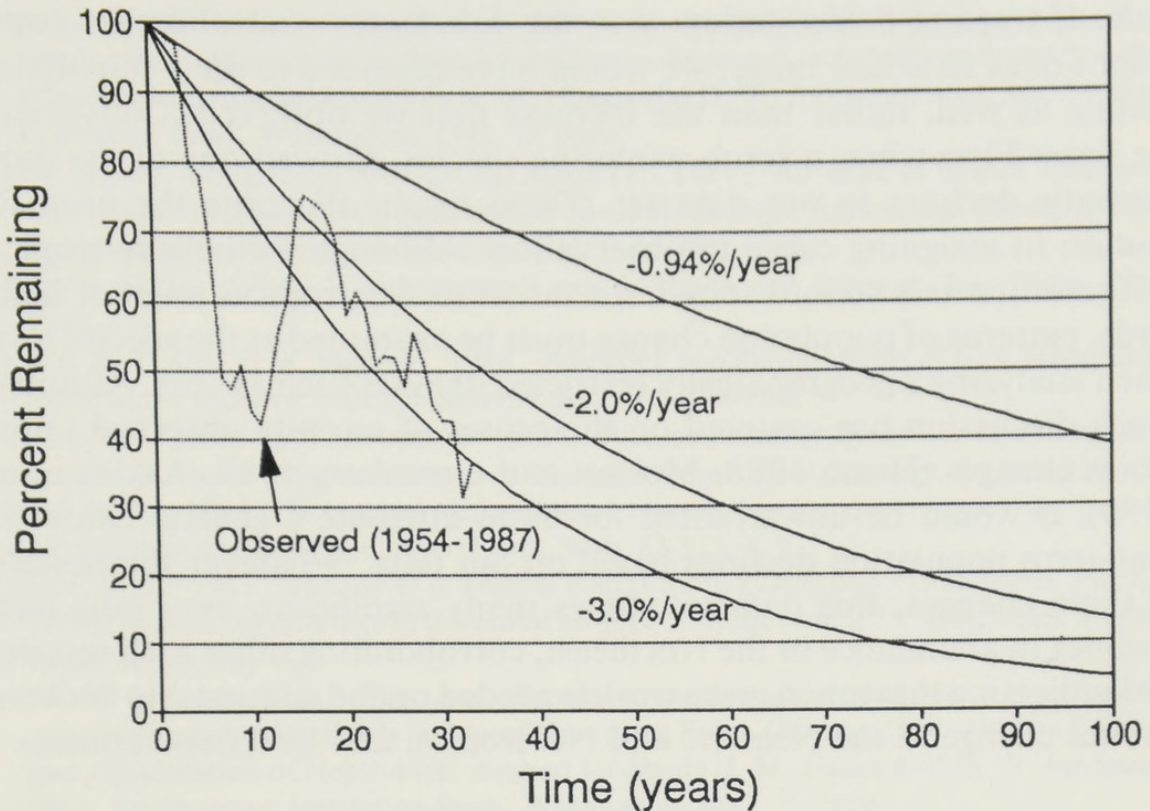


FIG. 2. Percent of populations remaining over time based on: (1) the annual mean rate of change for 26 Neotropical species (-0.94%), (2) a hypothetical 2% and 3% rate of decline, and (3) actual observed numbers of Neotropical migrants per hour of effort, ignoring species, using only the Hill data (smoothed data, 1954–1987).

to define the scope of inference (Atwood, in press, Hagan et al., in press). Origins and destinations of migrant birds sampled in this study were not known, but breeding destinations were almost certainly north of the censused areas. For this reason, the sample of migrants in this study represents populations of regional extent. Scale is an important consideration in interpretation of trend data, because species' trends can differ in slope and significance, depending on the region of study (Sauer and Droege 1990, James et al., in press, Sauer and Droege, in press). Thus, our conclusions should not be interpreted as representing the range-wide changes in species.

Observed results in this or any population monitoring study might be caused by habitat changes along migration routes, changes in breeding habitat, changes in wintering habitat, or any combination thereof. However, for some species in the northeast, such as the Blue-winged and Golden-winged warblers, and the Least Flycatcher, the primary force driving the population changes have most likely been a result of breeding ground events. The Blue-winged Warbler was described by Robbins et al. (1989) as a forest-wintering species that was decreasing on a continental

scale. If tropical deforestation were the sole factor controlling its populations over its entire range, we would have expected to see a population decline as well, rather than the increase that we observed. Conversely, the Least Flycatcher, a scrub-wintering species, showed one of the most dramatic declines in our data set. These results illustrate the need for caution in assigning cause to observation. Although we believe tropical deforestation is a serious long-term threat to Neotropical migrant landbirds, patterns of population change must be examined at the species level when analyzing a geographically restricted data set such as ours. Although much discussion has centered on the causes of recently observed population changes (Hutto 1988, Morton and Greenberg 1989, Askins et al. 1990), it would be unwarranted for us to attribute a general cause for long-term population declines based on our data. Whatever the cause(s) of these changes, this data set shows many significant, very long-term declines in abundance in the Northeast, corroborating other such reports, and indicating that much more work is needed on the relationship between habitat change in the Nearctic and Neotropics, and bird populations.

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